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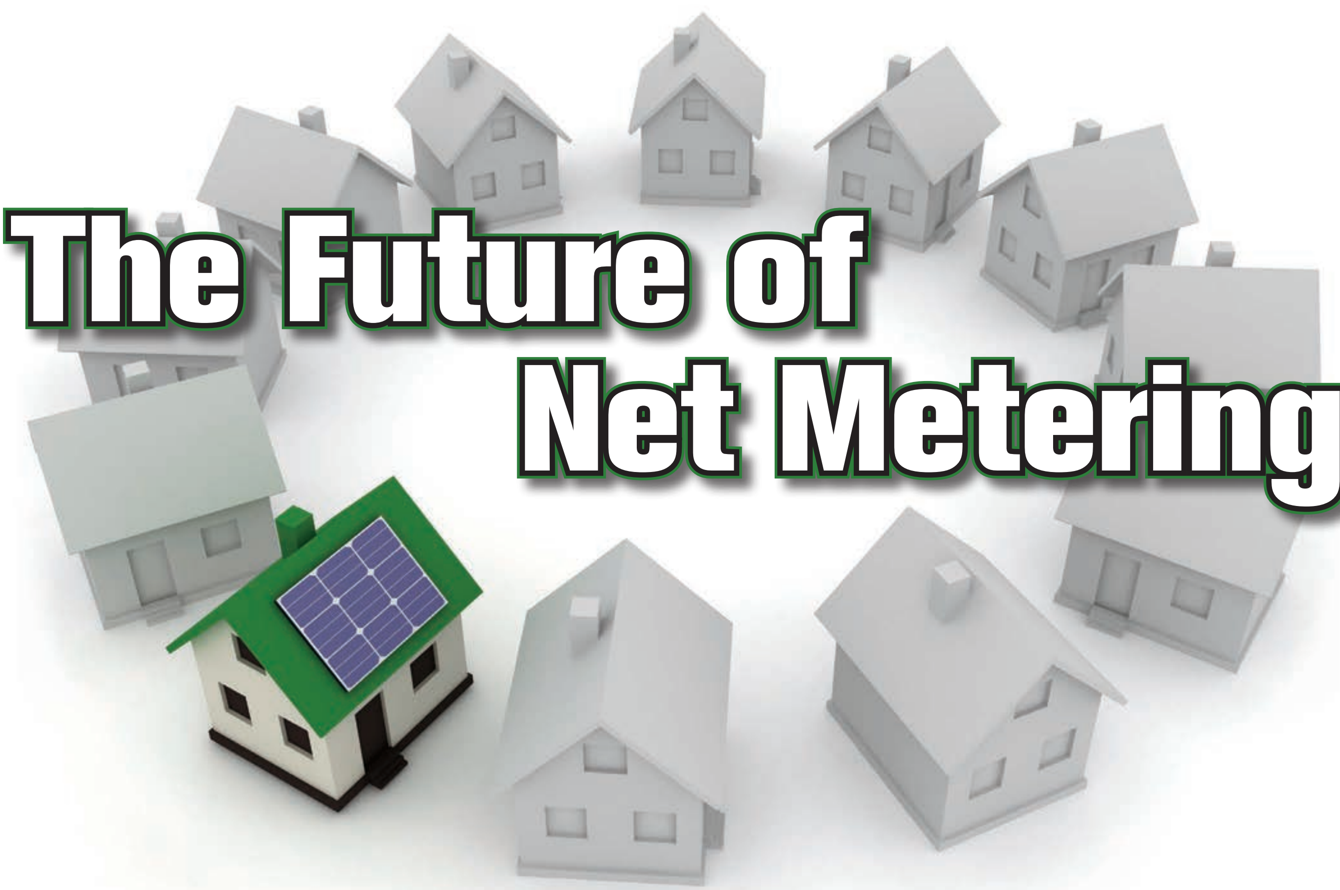

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This Year, Make RE Your Message

Hugh Piggott

Groups and individuals are scrambling to figure out what having a new president means to them and the issues they care about—and what they can do to make progress in those areas. The renewable energy industry and its supporters are no different. It's still early to be sure about how solar and wind will fare, but if post-election stock prices were any indication, renewable energy might take a hit—while coal stock prices have soared, according to *The Washington Post*.

However, a report from The Conservative Energy Network says there is strong support from conservative voters for renewable energy, including the federal tax credits, which help keep rooftop solar going strong. Balloting in Nevada, Wisconsin, and Florida halted utility efforts to cut solar energy support, which affirms public desire. Between U.S. pro-RE opinion, and global drive pulling the U.S. along, RE progress may not be significantly harmed. Industry growth will likely be slowed, however—it remains to be seen how much.

Citizen participation is more critical than ever in a new political climate that will likely be less friendly for renewables and potentially catastrophic for the global environment. If you want to foster positive energy policy and security, and support renewable energy and all of its contributions, such as jobs creation and clean air, here are some of the things you can do to help:

- ✔ Join local and national solar and renewable energy organizations, such as the American Solar Energy Society and Vote Solar.
- ✔ Let the president and your Congress representatives know that RE, efficiency, and conservation are key to maintaining a high quality of life in the United States.
- ✔ Instigate letter-writing, email, and phone-call campaigns about supporting renewable energy and energy-efficiency projects to newspapers, Congress, and the president. Post on their social media pages, but keep it on-message and positive. Make points about how effective RE is at creating jobs; increasing energy independence and national security; and keeping our air and water clean and safe.
- ✔ Act locally—our city and regional leaders are not as beholden to nonrenewable energy interests as our federal leaders are.
- ✔ Share your RE projects with local media.

—Michael Welch, for the *Home Power* crew

Think About It...

"A dramatic expansion of solar power is a clean and economical way to help break our dependence on foreign oil, reduce greenhouse gas emissions that cause global warming, improve our geopolitical position, and create good-paying green jobs."

—Senator Bernie Sanders, May 2010, upon introducing a bill to put 10 million PV systems on roofs

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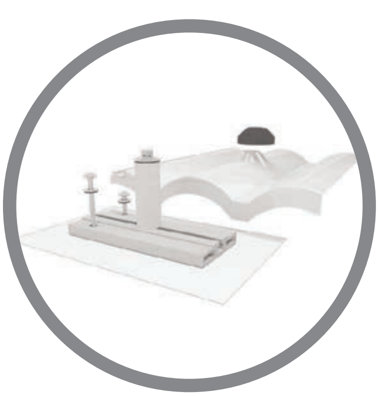
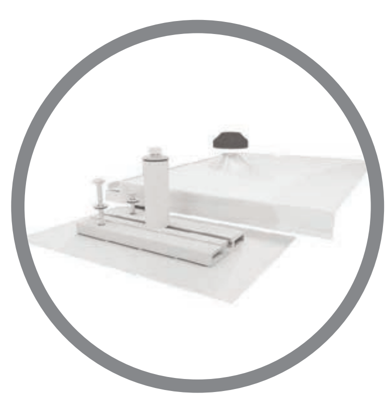


W Tile Mount

S Tile Mount



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On the Cover

Net-metering programs in the United States have helped foster the growth of grid-tied PV systems.

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Brian Mehalic is a NABCEP-certified PV professional, with experience designing, installing, servicing, and inspecting all types and sizes of PV systems. He also is a curriculum developer and instructor for Solar Energy International and an independent contractor on a variety of PV projects.

Michael Welch, a *Home Power* senior editor, is a renewable energy devotee who celebrated his 26th year of involvement with the magazine in 2016. 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.

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.

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. Justine has been an instructor with Solar Energy International since 1998, and 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.

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, and lecturing, teaching, and consulting with homeowners.

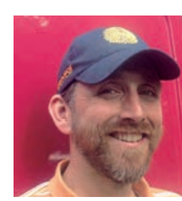
Chris Magwood is obsessed with making the best, most energy-efficient, beautiful and inspiring buildings—without wrecking the whole darn planet in the attempt. He is a founding director of The Endeavour Centre, where he brings this passion to life.

Dave Strenski and his family have lived in Ypsilanti, Michigan, for more than 17 years. His full-time job is working as an application analyst for Cray Inc., a company that manufactures high-performance computers. Dave holds degrees in surveying, and civil and mechanical engineering, and has been playing with solar power since 2005.

Carol Weis is a IREC-certified Master PV Trainer and NABCEP PV Installer. Carol was a lead member of SEI's PV technical team for 15 years, and now primarily focuses on helping other solar training programs establish themselves throughout world. Carol has advocated for inclusion of women in the energy sector by teaching all-womens' classes since 1999.

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.

Brent Summerville is a professional engineer in North Carolina and president of his engineering firm, Summerville Wind & Sun. He started his career in graduate school at Appalachian State University, and has designed, installed and repaired wind, solar, and microhydro systems for more than a decade. He now teaches in the Sustainable Technology program at Appstate.



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, a NABCEP Certified Solar Heating Installer, and an instructor for Solar Energy International.

Christopher Freitas is an engineer and project manager for international RE projects around the world. He was a cofounder of OutBack Power Systems and director of engineering at Trace Engineering, both located in Arlington, Washington.

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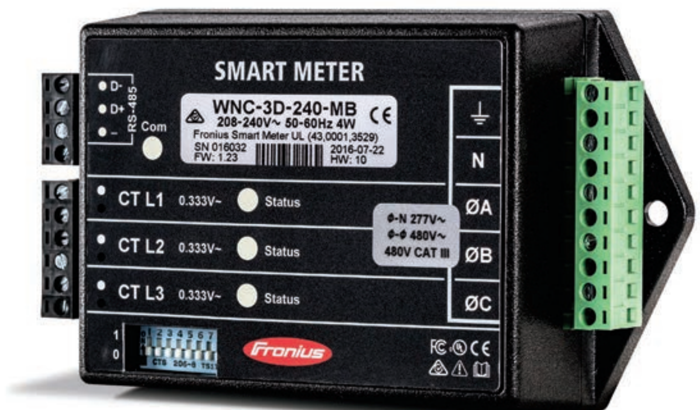
Home Power works with a wide array of subject-matter experts and contributors. To get a message to one of them, locate their profile page in our Experts Directory at **homepower.com/experts**, then click on the Contact link.



Courtesy Fronius

Fronius Smart Meter

Fronius (fronius.com) has a new bidirectional energy meter for feed-in management and energy consumption monitoring. The feed-in management function monitors the building's electricity consumption and communicates with the inverter to limit grid output, which is useful for systems that are limited in the amount of power they can export to the grid. The Smart Meter communicates with the Fronius online platform Solar.web to display an overview of a building's energy consumption so that users can compare to their PV system's production and adjust load usage to maximize self-consumption of their PV-generated energy. This meter is compatible with the Fronius Galvo, Primo, Symo, and the upcoming Primo Hybrid inverter lines.

—Justine Sanchez

Courtesy Lumos

Lumos Solar

GSX Bifi Module System

Lumos Solar (lumossolar.com) has developed its GSX Bifi Module System, a glass-on-glass frameless module that generates energy from sunlight on the module's face and from ambient light on the module's back. The GSX system has integrated weatherproofing, and concealed junction boxes and wiring—key features and aesthetics for shade structures and awnings. Face power output is rated at 275 W STC. With reflected or ambient light underneath, the power rating is boosted to 305 W STC. UL certification is pending.

—Justine Sanchez

Comment & Discuss this article @ homepower.com/177.14

PV Installations for Nonprofits

Made up of a loosely knit group of volunteers, SolarYpsi provides free education about solar power, and also designs and installs PV systems in and around Ypsilanti, Michigan. Over the past decade, SolarYpsi has given presentations to about 5,000 people at various local events. We hope to make Ypsilanti a "solar destination"—a place to learn about solar power from hundreds of examples around town.

Early in 2015, a non-local benefactor contacted SolarYpsi wanting to fund more PV installations in Ypsilanti. Since SolarYpsi is not a 501(c)3, it was determined that the best course of action would be to put together a list of nonprofits interested in having a PV system and the donor would choose from the list.

Within a few days, SolarYpsi volunteers created a list of 14 organizations, selected based on suitability for a PV installation. Besides being a charitable organization, the nonprofit needed to have suitable space for a 5 kW grid-tied PV system. Another preference was that, once installed, the PV system would be visible to the public from the street.

The selected recipients included a public library, two community centers, a public high school, a health center, and a city-owned carport. All told, the donor contributed a total of $93,000.

Combining the projects into one large job was key to attracting competitive bids and eliminating administrative costs on the part of the recipient organizations. With SolarYpsi evaluating the bids, neither the donor nor the recipient groups needed to divert time away from their own work. Three local contractors submitted bids; the donor chose SUR Energy, which bid an average installation price of $3 per watt across all the locations. This was a much lower price than what the organizations could have obtained if each project had been bid separately.

The Senior Center's rooftop, ballasted, 3,250 W subarray.

PV installations are a great way to provide support for a nonprofit organization. Reducing an organization's utility bills frees up money in their operating budget that can instead be used for their programs—it's akin to having a 30-year annuity. A librarian summed it up like this: "Now we will have more money to buy books!" Beyond dollars and sense, PV installations provide positive visibility for the organization, serving as an example of the organization's commitment to a brighter, better future.

—Dave Strenski • SolarYpsi founder

Dave Strenski below the 1,750 W awning subarray on the Ypsilanti Senior Center.

Courtesy Solar Ypsi (2)

Overview

Project name: Ypsilanti Senior Center*

System type: Batteryless grid-tied PV

Installer: SUR Energy

Commissioned: May 31, 2015

Location: Ypsilanti, Michigan

Latitude: 42.2°N

Average daily peak sun-hours: 4

System capacity: 5 kW STC

Average annual production: 6,331 AC kWh

Equipment Specifications

PV modules: 20 SolarWorld, Sunmodule SW 250 mono, 250 W STC

Inverter: SolarEdge, SE5000A-US (with Power Optimizers), 5 kW

Array installation: Roof and awning mount, UniStrut for awning, AET Rayport-B on the roof, south-facing, 38° tilt on awning, and 10° tilt on flat roof

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DIY Ground-Mounted PV System

One of the things we've appreciated most about *Home Power* over the years is the practical advice and real-world project descriptions in every issue. With inspiration from several articles, we first put in a small 1.5 kW rooftop grid-tied PV system in 2006. Some major home remodeling in 2012 and 2013 required removing that system due to roofline changes that caused additional shading of the array. Not wanting to go without solar, we decided to instead install a larger ground-mounted PV system (once our budget recovered from the remodeling) in our backyard, where shading was not a problem.

We had already been doing some research on ground-mount hardware options in late 2014 when *HP164* arrived with an article by Willi Hampel on a custom PV installation with a ground-mount rack system of his design. We immediately identified that design as a contender for our backyard installation since it hit all of our main requirements:

- A tilting rack design to allow optimizing array angle for the season, as we had with the Unirac rack system on our rooftop array. The tilting capability was also important to us for the same reason cited in the article—we are at nearly identical latitude (43°N) as the author's location, and snow shedding in the winter is critical given our usually abundant lake-effect snowfall courtesy of Lake Ontario and Lake Erie.

- A rack structure that did not take up too much linear space for our goal of 5 to 6 kW of PV capacity (we couldn't quite fit a single row of modules at that system size).

- A design that we could build ourselves, since we tend to be extreme do-it-yourselfers.

By the spring of 2016, we were ready to finally move forward on the backyard PV system. We again researched all available mounting options, but still didn't find any other designs that really fit our requirements and budget. The Hampel design was clearly the best option for our site, especially since the design assumptions for worst-case snow loading and wind speed were suitable for our location as well. So, in late May, we broke ground on the project with the kids laying out the orientation of the racks relative to true south and digging the holes for the steel I-beam supports of the tilting racks. The whole family helped out with cutting and painting lumber, assembling racks, installing I-beams, mounting PV modules, rack wiring, trenching cable, etc. Normal summer distractions added some extra weeks to the project, but not long after Labor Day, we threw the switch and the system started producing electricity. Our power company (National Grid) was very cooperative with the grid-interconnect approval, and the local permitting and inspections went off without a hitch.

Courtesy Tim Heywood

Our system consists of 20 Canadian Solar 320 W PV modules with a series string of 10 on each rack. We selected an SMA Sunny Boy 6.0 grid-tied inverter (with built-in Wi-Fi for monitoring—times have changed since 2006)! We mounted the inverter on the rack's center I-beam, and we trenched in four-wire #2 aluminum URD cable for the long run at 240 VAC to the house to keep wire losses low. Our existing 200 A load box allowed for a simple backfed breaker interconnection even with this larger system, and we were able to reuse the utility disconnect switch from our previous system.

The final project's cost was just under $13,000, and with the 30% federal tax credit combined with the 25% New York state tax credit and our fairly high electricity prices, we estimate a payback period of no more than six years. It was a big job putting in a system of this size ourselves, but it was a great family project and very educational for our three kids, extended family, and friends who helped out. Willi Hampel provided great input on some of the finer points of the design along the way and we're grateful he decided to submit his story to *Home Power* and share this great design. Our new PV system is now producing as expected and we're looking forward to many sunny days!

Tim & Stephanie Heywood •
Honeoye Falls, New York

Diesel Fuel for Generators

After reading Michael Welch's article in *HP176* on generator fuels ("Back Page Basics"), I felt that diesel was given short shrift on its many advantages (in no particular order):

- You can purchase diesel generators in "quiet diesel" configurations.

- Diesel generators usually last much longer due to the lower running speed (1,800 rpm) compared to 3,600 rpm for other fuels.

- Diesel fuel is a lubricant, so the engine's cylinder walls are not usually dry upon startup.

- Diesel fuel is not considered "flammable," since its flash point is way above ambient temperatures. It is a "combustible" liquid.

- Diesel is a higher-Btu-content fuel so it uses less fuel per kW or horsepower.

- As far as storage and fuel degradation, when I was 12, a friend of mine and I were in a pasture his family owned and we ran across an old crawler tractor (1920s?)

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with weeds growing up through it. Even though the tractor had been sitting there for the last 20 or so years (in the high desert), we managed to crank-start it and drove it around for half an hour up and down hills and through the creek bed—and parked it in the exact same spot so his father wouldn't notice. It seems that as long as the tank is full and it is in a dry environment, diesel lasts a long time...

Vince Bond • via homepower.com

Thanks for sharing those points. Diesel, biodiesel, and vegetable oil generators are definitely worth considering, for the reasons Vince noted. I'd add that diesel can be susceptible to microbial growth, which can contribute to clogged filters, pumps, and injectors. I'm not sure how keeping a full tank changes that, though I can see how it might help keep out condensation. There are additives to put into diesel fuels that can extend storage life and prevent microbial growth—and the resulting formation of contaminant buildup.

Michael Welch • Home Power *senior editor*

Rolling on Sunshine

Brett Belan's *HP176* cover story on converting his VW van to solar electricity is totally inspiring, in multiple ways—his family's personal commitment to "slowing down," his technical expertise, and his attention to detail. I have bicycled the Pacific coast and generally had wonderful respect from most drivers. I drive regularly 4,000 miles from New Mexico to Alaska at 55 mph, getting significantly better mileage than my speeding neighbors on the road. In this time of limited resources, technology will not save us. We all will serve the planet to slow down and do more with less.

Carl Rosenberg • via homepower.com

No Thanks to Black Modules & PV Shingles

I will never understand why people will pay a premium for high-efficiency solar-electric modules, and then buy modules with black frames and black back-sheets, and install them with low clearance on a black roof. If the aesthetics matter that much, you might as well buy the lowest-efficiency panels, right?

As far as using PV shingles, not only have they not proven themselves thus far, they are a pain to wire and service. Do I really want to open up my roof to replace a single PV shingle? Elon Musk and his followers are touting this as if this was some great new innovation. It is not. It might appeal to those who care a lot about how the roof looks. I predict many of those systems could become boat anchors in time and require a reroof to upgrade to a newer PV system. They are not going on my roof, either.

Marc Fontana • via homepower.com

Utility Charges

Regarding Tom China's letter in *HP176* ("Mailbox") on utility charges, if you look back in time, there are a lot of similarities between what the electric utility industry is going through today and the telephone industry went through back in the '70s, '80s, and '90s. When I worked for a telephone company, its approach was: "We may be the only phone company in town, and we sure do act like it!" Does that sound like the local utilities today? Back then, the phone companies were guaranteed a specific rate of return, and I believe that is still alive and well in the electric utility industry. Maybe they should be a "nonprofit" organization, which would eliminate the need to increase profits for shareholders. Look around you and see where that "only one in town" approach got the phone companies.

Competition was finally allowed (as solar is to the utilities now) and then there were many communications companies created (some supplying voice, cable, data, and equipment). Back in the '60s, you could "get any color phone you wanted, as long as it was black." Look around you today and see where competition and technology took us—from landlines and black phones to cellular, satellite phones/data and VOIP. Things change, and in this case, it was for the better.

You can compare the electric utilities' future to the petroleum industry's current condition. Supply is greater than the demand. With the transition to more fuel-efficient cars, the gas industry is still producing fuel, but they will gradually make adjustments. The way I see it, the utilities will still be producing electricity even if solar-electric installations are allowed to expand in the future (fewer restrictions, more incentives), but the electric companies will have to adapt to its new competition. The point is that they will need to become more efficient in production, distribution, maintenance, and support, and learn how to survive in a competitive marketplace—and not bury their heads in the sand by trying to block the inevitable.

If you look at the homes on my city block, only three of the 24 homes can use rooftop solar energy because of shading, so it is never going to be 100% solar, just as it will never be 100% electric automobiles. I am one of the lucky ones in the neighborhood who can have solar electricity at my house (6 hours of no shade).

So, what is it that really turns off consumers about big power utilities? Where we live in Florida, Duke Energy is the provider, and we are paying for a nuclear power plant that will never be built. I will bet you that those funds will never make it back into our pockets, and we will be paying for the "power plant on paper" for a long time to come. Unless, of course, the elected officials see the writing on the wall.

As long as you have stockholders in the electric utility industry equation, you will always have higher rates, as they will always protect their bottom line for the stockholders. Look at Nevada—the elected officials there allowed the utility company to levy higher fees on net metering customers, making it less desirable to install solar-electric systems.

Fortunately, we here in Florida just voted down Amendment No. 1 on the November ballot (not by much), which would have allowed Duke Energy to add fees and other restrictions to home PV installations. I guarantee that Duke Energy will be back within two years with another attempt. Their advertising campaign made it look so appealing, like it was going to be beneficial for both sides of the solar coin.

The electric utilities are where the phone companies were in the '70s—unwilling to accept change and new technology that will have an impact on their profits and future. They, like the phone companies, did not know how to compete in a competitive environment. The electric utilities now have the opportunity to refocus on the future, and accept the fact that homes and businesses will be powered by renewable energy or whatever else future technology brings. It sure will be an interesting future!

Don Houdek • via e-mail

Off-Grid Refrigerators

In the *HP176* article, "Choosing Your Off-Grid Refrigerator," a sidebar discusses off-grid fridge vagaries. The problems with the refrigerator that author Dan Fink reported on are by no means universal. Many of the most efficient refrigerators today have variable-speed compressors. These use electronically commutated, brushless DC permanent-magnet motors. The electronics inside the refrigerator rectify the incoming supply, and then feed it to the compressor motor. Such motors typically do not have the high in-rush start currents that are the hallmark of fixed-speed induction motor compressors.

Provided the incoming supply does not emulate sine-wave power by including overvoltage spikes high enough to "kill" the

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electronics, the fridge doesn't care what the wave-form is like. (The same is also true for electronically commutated, brushless DC washing machines.) When the electronics in the refrigerator are run off this internally rectified supply, they should also be oblivious to poor incoming waveform.

Understandably (though more's the pity), appliance manufacturers do not typically check out or certify their appliances against the vagaries of various off-grid power suppliers, or even list information as to what is the minimum acceptable specification for such power. With a bit of research, the problems that Dan experienced should have been able to be avoided just by selecting an appropriate refrigerator—avoiding problems with the GFCI, waveform, and inrush overload problems tripping his second inverter.

While manufacturers should be willing and able to advise whether or not a specific model is likely to have problems in specific installations, don't necessarily expect them to cover their appliances for problems originating in your power supply.

Lindsey Roke • Fisher & Paykel Appliances

For our off-grid cabin, we bought a basic model, standard upright refrigerator/freezer (separate doors, freezer on top, no ice maker) in the $450 range at the big orange box store. We have had no problems with our solar/battery/inverter running this unit, although I have minimized other loads in the cabin. The ironic twist comes that we have to empty out perishables from the *freezer* in the winter.

As the only heat sources in the cabin are the antique cylinder stove in the lower level and the Rumford design fireplace in the "great room;" there is no heat when human beings are not present to tote firewood and stoke the fires. We designed all the plumbing to completely drain with a few valves, and "pink" the toilets and p-traps with RV antifreeze when we leave. At 8,500 feet elevation in the Colorado mountains, the "usual" temperature when we arrive in the winter is in the low 30s (we have a couple of days every winter where the recorded temperature inside the cabin is below 0°F). This basic refrigerator runs its compressor based upon the temperature in the fresh food compartment—not the freezer. So, when the cabin is resting in the low 30s when we are not there, it may be several days before running the compressor, and the freezer temperature will rise above freezing, thawing foods enough to compromise safety.

While there are many potential solutions to this problem, for the near term, we just pull out all the perishable frozen foods by about Halloween. This serves as a good annual clean-out-the-freezer exercise.

Meredith Bond • via email

I don't live off-grid, but bought a new 22.1-cubic-foot Maytag fridge with a bottom freezer in 2012 because it had the lowest rated energy usage for its size—404 kWh per year. It saves energy by monitoring the ice buildup on the evaporator, and only defrosts when needed.

I learned that in 2014, the U.S. EPA changed the energy-test requirements for refrigerators. This has resulted the Energy Guide posting higher energy-use numbers. The newer Energy Guides have yellow text over black (previously it was the reverse). As a result, the cards now have different energy numbers posted on the black/yellow Energy Guide (U.S.) side and on the white EnerGuide (Canada) side. It's confusing because the numbers can be quite different. For example, the model I own is still sold, but it now has a 584 kWh per year rating in the United States, but in Canada, it is rated at 423 kWh per year.

All of this makes it very difficult to compare the energy ratings between older and newer models. If you want to compare in the store, you can use the Energy Guide, but I wouldn't trust the rating to give an accurate energy consumption value.

Marc Fontana • via email

I have been doing off-grid design and construction since 1987, and have things changed—refrigerators included. Up until a few years ago, I recommended only propane fridges for part- and full-time off-grid homes. That's what I have in my part-time cabin. That way, you can leave food in it while gone, since I recommend turning off the inverter system when leaving for more than a few days. For homes occupied part-time, I still recommend that—because, even with DC fridges, if something goes wrong and you kill a battery bank, that's far more than the cost of a new fridge.

I have started recommending new Tier 3 (20% more efficient than the federal standards) Energy Star fridges for full-time and some part- time homes (but you have to empty the fridge when you leave and still turn off the power). The low power draw of the best Tier 3 models is an easy add-on to an AC-powered solar home. If you want to be extra conservative, put a timer on it so it only runs from 7 a.m. to 7 p.m. each day to conserve energy overnight. With the low cost of PV modules, it's not a difficult option to plan for.

Clark Gestring • via email

Our full-sized refrigerator uses 150 watt-hours per day and cost under $300. After years of hauling propane tanks to our remote home, many years ago I found a previously unused, top-opening chest freezer $150. For an additional $110, I put a mechanical thermostat at the freezer's AC outlet. I set the mechanical thermostat to 40°F, ran the temperature probe into the freezer, and plugged the freezer into the thermostat outlet bypass. Thus, the freezer was turned into a refrigerator since it is depowered when it reaches 40°F—a standard refrigerator temperature.

Based on multiple readings using a Kill-A-Watt meter, the freezer-turned-fridge consumes 150 Wh per day (0.15 kWh per day), which is less than a quarter the rating of the *best* Energy Star refrigerator listed on refrigerator comparison websites. Our experiment did require that we get used to top-loading organization for our groceries, but this was easier than we thought it would be. In addition, we can open the fridge and leave it open for 15 minutes or longer without the guilt associated with the cold air dump that occurred every time we opened our front-loading propane refrigerator.

This option also turned out to be much less expensive (and as effective) than buying a DC refrigerator. All of those were priced in the thousands of dollars and were significantly smaller.

The experiment was so successful that a few years later we added a second top-loading chest freezer on our back porch (placed there to reduce its energy use during our cold winters). We paid $150 again for one we found on Craigslist, and can attest that it uses an average of 450 watt-hours per day around the year (0.45 kWh/d) without any modification, a significant energy savings from all of the other upright front-loading freezers we compared.

The thermostat is available from Backwoods Solar. Many other mechanical 120 VAC thermostats will work, as long as they have an external temperature probe.

"Escape Artist" • via email

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Courtesy Roy Rakobitsch

Off-Grid Wind?

I've built a small off-grid cabin on a thickly forested property in central Ontario, Canada. The two-story 16-by-16-foot cabin has a 12:12 pitched roof. I work in town a lot of the time, and built this cabin for taking our kids there a maximum of two days a month. There are two upstairs bedrooms, each of which will have one main light and two outlets. The main floor will have a maximum of eight outlets and five lights. There is no water in the cabin. Space heat is fueled by propane; so is the cooktop and fridge.

I was planning to buy six Trojan deep-cycle 6-volt batteries and a Coleman 400-watt wind turbine and charge controller. For the record, I have zero experience with this off-grid stuff, but I'm a licensed electrician. All the lights and kids' nightlights will be less than 8-watt LED bulbs.

Do you think this small turbine and batteries will be enough for two overnight visits a month and for a total run time of 5 hours each time? Any help would be greatly appreciated.

Jason Summerfield • Ontario, Canada

If you have such thick woods that you can't use solar energy, you also will need a tall tower well above the trees to capture any wind energy. The standard rule for tower height is to get at least 30 feet above anything within 500 feet—an expensive proposition. If the mature tree height in your part of the world is, say, 60 feet, you'll need at least a 90-foot tall tower. Do the math for your site, and round up. The photo above shows you what your wind turbine should see—lots of view.

Wind-electric systems also take care and maintenance that solar-electric systems do not need, and tend to have a higher failure rate. Putting a wind-turbine on a site that is largely unattended may not be the best idea.

Choosing your battery size and configuration at this point is premature. Your idea of six, 6-volt batteries would mean a 12-volt system, when you may actually want a 24- or 48-volt system, depending on your loads and overall system design. The total watt-hour capacity desired is the best place to start with battery design. And a "400-watt" wind turbine is not a very meaningful description. What you actually need to know is how much energy (kWh) a machine will produce in your wind resource (average wind speed).

You made a good start on the first step in any off-grid design process—load analysis. I'd encourage you to continue it beyond "XX lights and XX outlets" to actual watts, hours, and ultimately kilowatt-hours (kWh) per day. This will give you a real load target to design your generating system to handle. Using the most-efficient lights and appliances possible will shrink the size of the generating system needed.

Next, take a closer look at your resources. A solar site analysis might tell you that there's more sun than you think, or you might find a "creative" way to get some PV modules up into the sun. In my neighborhood, savvy and handy folks sometimes put PV arrays in trees, on high roofs, or even on towers.

It's wise to look at your wind resource more carefully, too. Not every location has a good wind resource, so find out how much your site has (the average wind speed) before installing a system.

You also might consider a fuel-fired generator, which may be needed as backup anyway. A battery bank with inverter/charger can give you AC, and the ability to charge from a generator. Adding PV and/or wind can make the generator a minor backup player, which is a good role for generators.

Your project may be quite attainable, especially because it's only for occasional use. But careful analysis of your load and its timing; the needed storage capacity (battery size); and your charging resources are necessary to make it all work. You could take a "learn as you go" approach, and it's a good adventure, but a bit more study and number-crunching could save you from expensive mistakes and disappointment.

Ian Woofenden • *Home Power* senior editor

Idle PV Modules & Battery Failure

My PV array consisted of two strings of four 125-watt Kyocera modules, and one string of four 130-watt Kyocera modules, with three 48 V strings going into the combiner box. They fed two strings of eight 6 V golf cart batteries.

Four years ago, after the batteries failed, I deactivated the system. Although I intended to buy new batteries right away, I have delayed it this long because of the expense. Does it hurt PV modules to be left up disconnected for that period of time? Should I have disassembled the rack and stored them away?

In the meantime, the combiner box has failed, so I need to replace it. Can you recommend a replacement? I was thinking about installing a DIN-rail DC circuit breaker box and installing a pull station for external/emergency disconnect. Would just circuit breakers suffice for a combiner box, or are there other considerations to selecting combiners?

James Jennerman • via homepower.com

It is tricky to give advice on systems from afar, as there can be many factors that we can't ascertain without inspection. The best thing to do is find a local PV installer with battery-based system experience.

Disconnecting the PV modules won't damage them, but there will still be degradation from sunlight exposure—less than 1% per year (some studies say 0.5% per year). Before recommissioning, check for array (and wiring) damage from past storms or critters. Then your

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Courtesy MidNite Solar

Disconnecting combiner boxes offer PV series string overcurrent protection and an array disconnect (not shown) in one UL-listed package.

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48 V system will simply need new batteries and a combiner box. There are disconnecting UL-listed combiner boxes that give both combiner and disconnect in one box. The manufacturer or retailer's tech support can help you figure out the breaker ratings you will need (voltage and amperage).

Spend some time investigating why the batteries failed. Were they just at the end of their normal lifespan (five to 10 years for typical flooded lead-acid batteries)? If this was not the case, were they maintained well (watered regularly)? Did they reach a full state of charge regularly, or did they sit undercharged much of the time? Compare your loads to your PV array size, and make sure the battery bank is well-matched. Appropriately sizing an off-grid PV system takes some education—search back issues of *Home Power* for examples. Working with an experienced PV installer to evaluate your system as a whole will decrease the expensive possibility of replacing a prematurely failed battery bank.

Justine Sanchez • *Home Power* magazine technical editor

AC-Coupling Oddities

I need your assistance in resolving an issue with my Enphase 215 microinverters. I have four of them installed in a mini-grid using an OutBack GTFX3048 inverter capable of AC coupling. One morning, the microinverters failed to "wake up." I disconnected the PV cable to one of them, and when I reconnected it, they all started producing again. It happened exactly like this the next day—in the morning, there was no production until I turned off the AC switch briefly and restored it. What is happening?

Simon Edache • via homepower.com

This problem may have multiple causes and solutions. Without having access to the system and the ability to run tests, it isn't easy to determine why your system is malfunctioning. One of the first steps would be confirming the lack of power production, versus a communication problem.

Another possibility could be an issue with the voltage that the microinverters are sensing and their inability to lock into the battery-based inverter's output. If the AC output from the battery-based inverter is outside of the acceptable range for the micros, they will simply wait for a proper voltage before turning on. But it is curious that a hard reset on either the AC or DC side of the microinverters solves the issue, as that shouldn't impact the battery-based inverter's voltage.

Since you mentioned OutBack inverters capable of AC-coupling, I asked Phil Undercuffler at OutBack for some troubleshooting suggestions. He recommended verifying the wiring of the remote-operated circuit breaker, which is a control device specific to AC-coupled installations that lets the grid-direct inverters "see" the AC voltage required for operation. If this breaker isn't wired properly, it could remain in the "off" position, even though it should be on.

It is necessary to make sure all of the system components are compatible for an AC-coupled system. The OutBack AC-coupling solution is designed to work with multiple grid-direct inverters. This helps manage battery charging without requiring you to wire your own ad-hoc relay system. In addition, some grid-direct inverter manufacturers restrict the use of their inverters in AC-coupled systems. This is less of a concern than it has been in the past, but still worth verifying with your grid-direct inverter manufacturer, who might also have clues as to why your microinverters aren't waking up.

You also need to consider all the power sources present. If an engine generator is connected, you need to install controls that won't allow the grid-direct inverter(s) to connect to the generator's output.

Ryan Mayfield • Renewable Energy Associates

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Courtesy OutBack Power Systems

The OutBack GTFX series is one of several AC-coupling-capable, battery-based inverters on the market.

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Window Screens in Winter

Last year, we had most of our windows replaced with triple-glazed, argon-filled windows. We live in an extreme climate (-30°F is not uncommon in winter). I have been told that removing the interior screens in the winter helps improve the window's performance. Is this true? If so, why?

Gordon DeArmond • Saskatoon, Canada

As part of the annual winter preparation and maintenance, removing the screens and cleaning the glass—especially in windows oriented due east to south to due west—can definitely add meaningful solar gain to your home, especially if you have suitable interior thermal mass. In addition to free solar heat, feeling the full power of the winter sun coming through those southern windows on a bright day can cut down the need for supplemental artificial lighting and can improve one's mood.

One study by the Midcoast Green Collaborative measured the heat gain of an interior soapstone sample placed in front of a south-facing window on a sunny winter day. The temperature of the sample in front of a window with an interior screen was 88.7°F compared to 96.7°F on samples set in front of a screenless window. This was correlated with an approximate 30% loss of solar heat gain through the screened window.

My one concern with removing interior screens would be more one of human behavior. As the days warm in springtime, another useful passive way to heat up the home (besides solar) is to open the windows on warm afternoons and allow that fresh, warm air into the home. It's important to know yourself—will you have those interior screens installed again by the time those glorious afternoons arise? Or will you be stuck with your windows closed because you don't want that first wave of bugs flying in your windows?

Window screens can block as much as 30% of passive solar heat gain.

Stephen Hren

Stephen Hren • Durham, North Carolina

write to:

asktheexperts@homepower.com

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

The Farm at Mollie's Branch in Todd, North Carolina, is a small, on-grid farm that always finds itself on the local farm tour. This family farm features llamas, free-range chickens, stands of nettles, a shiitake mushroom nursery, and a rustic creekside cabin for visitors and interns. With aspirations of greater energy sustainability, the owners wanted to pursue an on-site, clean energy project, reducing the consumption of utility-supplied energy and directly powering critical farm loads, such as lighting and refrigeration.

Microhydro Upgrade

Story & photos by
Brent Summerville

Above: The Farm in the New River watershed of North Carolina.

Left: The main farmhouse also has a grid-tied PV array. The new hydro system is battery-based and uses the grid only as backup, when electrical demand exceeds hydro energy production.

Below: The hydro power shed, cleverly disguised as a log cabin.

The original hydro intake screen system was prone to clogging with debris and sediment.

The Farm has a creek running through the property that eventually flows into Pine Orchard Creek and then Elk Creek, a tributary to the South Fork of the New River. In 2006, the farm's owners, Diane Price and Rob Griffith, expressed interest in tapping the creek's energy and reached out to the local agricultural extension agent, who contacted Appalachian State University for assistance. A student club, the Appalachian State University Sustainable Energy Society (aka the Solar Club), visited the farm to assess the resource.

An estimated 100 feet of head and a typical flow of about 300 gallons per minute (GPM) was good news, and the farm worked with the local agricultural extension office in Watauga County, North Carolina, to receive a $15,000 Small Farm Innovation grant from North Carolina Agricultural and Technical University.

The system was designed to run part of the house on hydro energy while leaving some less critical loads on-grid. Critical loads were identified as refrigerators; barn loads (lights and chicken brooders); bedroom receptacles; a furnace fan; living room lights; kitchen receptacles; garage (lights and freezer); utility room lights; study lights; and kitchen lights. These loads were pulled from the main electrical panel and placed in a new subpanel. The battery-based hydro-electric system would run these loads, with the grid serving as backup if the hydro system was down or unable to keep up. Any excess energy from the microhydro turbine would be diverted to a resistance heater diversion load that warms the garage. Since no turbine-generated energy would be exported to the grid, there was no need to deal with the local utility.

The system was designed and installed by Appropriate Technology students at Appstate, and served as my class project when I was a grad student, using a good amount of student labor from the Wind and Hydro Power Technology class. This service-learning relationship served all parties well, enabling hands-on work in the creek for students, and greatly improving our experience and knowledge of what does and does not work in microhydro design.

The Original System

Diane and Rob reported a late summer low-flow of about 100 gpm, with a consistent flow of about 300 gpm for the rest of the year. Based on this information, a design flow of 85 gpm was chosen.

The original "headrace" was a 6-inch corrugated plastic pipe, a low-cost, simple diversion of water from the creek over to the intake. The original intake used two plastic pickle barrels and a screen—about 100 gpm from the diversion pipe poured into an upright 50-gallon plastic barrel that settled rocks, silt, and sand. The water then exited the side of the barrel and fell onto fine mesh, stainless steel screen, mounted to a second 50-gallon plastic barrel, placed on its side. In this barrel, fine silt was settled, with the flow routed into the 4-inch HDPE penstock bolted to the center of the barrel end. A 4-inch corrugated plastic overflow pipe above the penstock connection returned surplus flow to the creek. The screen proved to be somewhat self-cleaning. But emptying the first barrel of rocks and sand was accomplished by pushing it over; however, if it wasn't emptied regularly, the full barrel became too heavy to tip, so shoveling was necessary.

The Harris Hydro turbine on its treated and caulked plywood tailrace.

The penstock is 1,200 feet of 4-inch-diameter SDR17 high-density polyethylene pipe (HDPE). The pipe arrived in 50-foot lengths that were dragged into place and connected with a fusion welder into one long pipe to the turbine. Flanged couplings were welded onto the ends of the penstock for connecting to the intake up top and to the plumbing with manifold down at the turbine. The penstock has been a maintenance-free, reliable part of the system. It has not been damaged by freezing temperatures or fallen trees or rocks.

At the turbine end of the penstock, the HDPE transitioned to 3-inch PVC pipe and entered the log powerhouse after a 2-inch gate valve and bypass drain, which is used for purging the penstock. A pressure gauge shows pressure, followed by a 3-inch bronze gate valve, which serves as a main shutoff. The flow is distributed via a manifold to a four-nozzle Harris Hydro turbine.

The turbine housing extends down and out of the powerhouse and returns the flow to the creek. The turbine housing was fabricated using pressure-treated plywood and lots of silicone caulk.

From the turbine, the wire run travels about 250 feet to a 48 V, 200 Ah battery bank and Xantrex inverter/charger in the garage. The system feeds the subpanel of critical loads, and the inverter is programmed in low-battery transfer (LBX) mode to use the grid as a backup, depending on battery voltage. For example, if the hydro system goes down (due to freezing, clogging, etc.), the battery voltage starts to drop—the inverter continues to serve the loads, even though the recharging source is absent. During this time, grid power is used to both run the loads and recharge the battery. When the hydro system is brought back online, grid power is turned off, and the inverter will once again pull energy from the battery bank to serve the loads. All of this happens automatically through inverter programming; the loads stay on and the batteries survive the hydro downtime. When the system is generating more energy than the loads and battery can accept, a C40 diversion-load controller sends this electricity to an air heater.

Redundancy Required

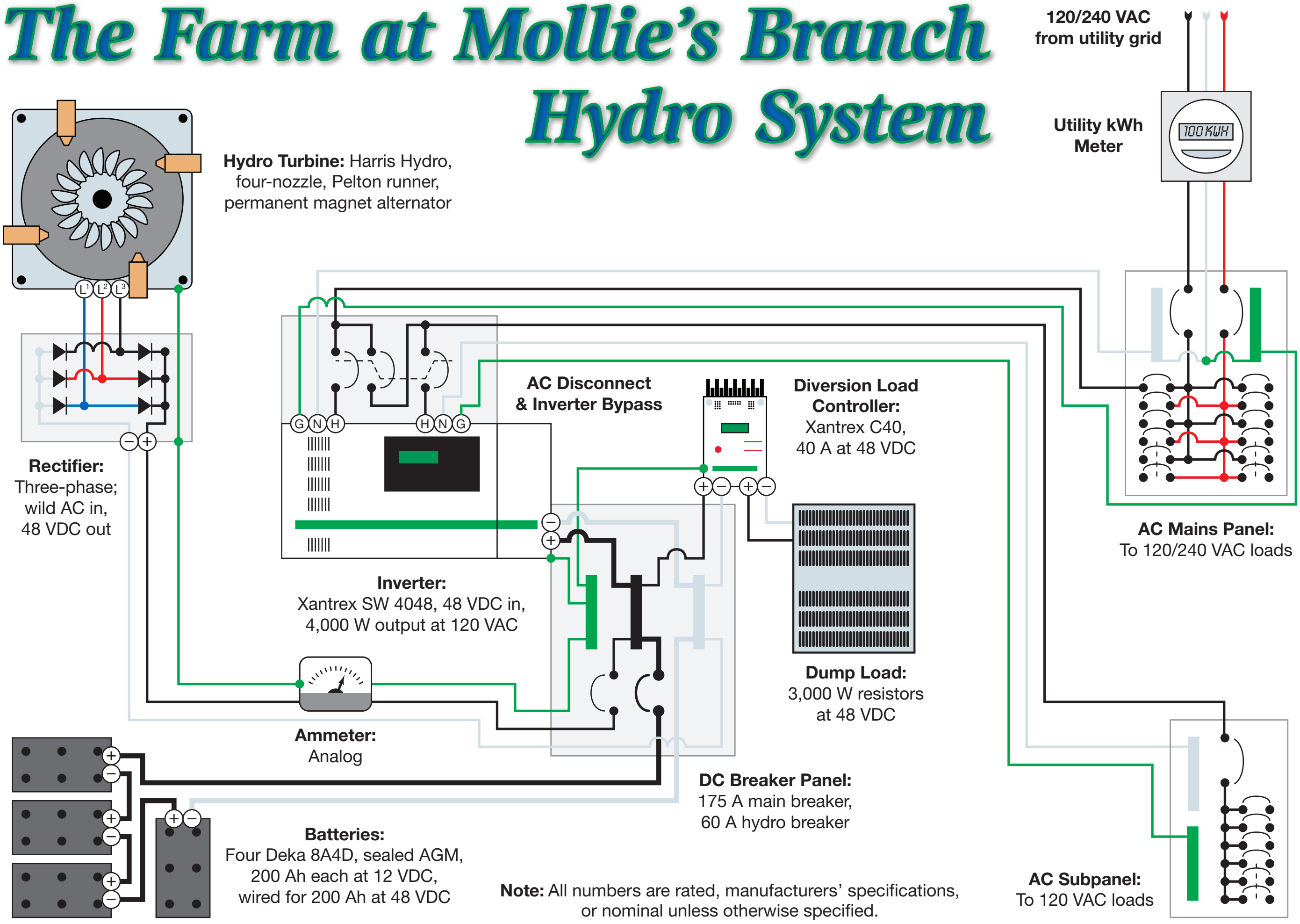
To comply with the intent of the *National Electrical Code*, hydroelectric systems using a diversion controller should be equipped with a second independent means of charge control to prevent overcharging the battery in the event of a component failure.

A Xantrex 4048 inverter powers the loads, while a C40 acts as a diversion controller, dumping excess energy to a 3 kW resistor.

Four Deka AGM batteries provide 200 Ah of energy storage at 48 VDC for dedicated loads.

A dedicated AC subpanel is served by the inverter.

The Farm at Mollie's Branch Hydro System



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

Tech Specs

Overview

System type: Battery-based microhydro-electric with grid backup

System location: Todd, North Carolina

Site head: 100 ft.

Site flow: 300+ gpm

Design flow: 60 to 100 gpm

Hydro resource flow (dry season): 100 gpm

Hydro resource flow (wet season): 300 gpm

Hydro production (dry season): 380 AC kWh per month avg. (12.6 kWh/day)

Hydro production (wet season): 610 AC kWh per month avg. (20.4 kWh/day)

Civil Works

Diversion: Impoundment of rocks & logs

Intake: 1 ft.^{2} Hydroscreen

Penstock: Originally 1,200 ft., extended 80 ft. for a total length of 1,280 ft.; 4-in.-diameter HDPE

Powerhouse: 10-by-12 ft. log shed

Hydro Turbine

Turbine: Harris Hydro 4-nozzle permanent-magnet, Pelton

Runner diameter: 4 in.

Alternator: 48 VDC output

Rated peak power output: 1.5 kW

Hydro Balance of System

Dump load controller: Xantrex C40

Dump load: Resistor bank from a Whisper 500 wind turbine, 3 kW

Inverter: Xantrex 4048 with power panel, 48 VDC nominal input, 120 VAC output

Circuit protection: 60 A breaker

System performance metering: Built-in ammeters and voltmeters in Xantrex inverter and C40 charge controller

Energy Storage

Batteries: Four Deka 8A4D, 12 V sealed AGM, 200 Ah @ C/20 rate

Battery bank: 48 VDC nominal, 200 Ah total

Battery/inverter disconnect: 175 A breaker

Appalachian State University students further reinforced the intake to slow water velocity at the screen, and added wood blocks to prevent leaves from catching on the Hydroscreen sidewalls.

Upgrade Time

After more than a decade in operation, failures at the diversion pipe, along with irregular intake maintenance, had compromised the system's performance, since the penstock wasn't always full. With a partially empty penstock, the pressure at the turbine drops and less energy is produced. The corrugated diversion pipe needed to be replaced due to many repairs—it was mostly a mix of tape and leaks. This pipe would wash out in crazy flood conditions; its saving grace was that it was relatively straightforward to reposition. With several blow-out incidents and a patched-up diversion pipe, maintaining a reliable diversion of flow had become challenging.

From time to time, sticks, bark, rocks, and crawdads escaped the initial screens, passing through the system to clog the turbine nozzles. Once as I was standing at the intake, explaining how it works to a tour group, a small brook trout flopped onto the screen. We returned the fish to the stream, but I've always wondered about others not so fortunate, and was in support of finding a fish-friendlier intake.

To improve the system's reliability, I suggested that the farm use extra penstock that was lying around to extend the penstock and upgrade to a self-cleaning Coanda-effect Hydroscreen intake. Diane and Rob agreed, and after consulting with Hydroscreen, an intake box was ordered.

Several students in my Wind & Hydro Power class visited the site for their class project and identified a natural impoundment for the new intake. The penstock was cut and extended 80 feet up to the new location. With student help, some logs and rocks were

The first step in the system upgrade was extending the penstock to a better location upstream, which gained a few feet of head, and installing a Hydroscreen intake. Note the cable-tie anchoring on the slippery HDPE pipe.

Above: Without a HDPE welder, the new penstock was joined with rubber couplers, which required bracing and anchoring against the forces of gravity.

Right: The finished intake—with tapered weir timbers and solid anchoring—is ready to weather the extremes of seasonal flow.

repositioned in the stream to accommodate the Hydroscreen, which was attached to the logs with lag screws. The penstock connected to the intake with a rubber coupling. The sidewalls of the intake seem to catch leaves, which narrowed the flow of water, so two 4-by-4-inch pieces of wood were added to the top of the impoundment to guide the flow into the screen and avoid leaf buildup. Hydroscreen company owner Bob Weir warned us about water flowing too fast over the screen, so we dredged and widened the creek just upstream of the intake to slow the flow over the screen.

The sand-blasted brass pelton runner (right) was worn completely through in spots. The new runner (left) is ready for another 10 billion revolutions.

Single-digit temperatures are common in winter, and the PVC near the turbine froze and cracked. In these cold temperatures, the water flowing in the pipe appears to slowly freeze from the outside in, constricting the flow. This constricted flow then clogs from ice chunks, sometimes stopping the flow and contributing to full system freezing. Our hopes are that the intake upgrade will result in less turbulence, less ice-chunk formation, and thus no full system freezing.

At the time, there was no locally available HDPE pipe fuser and a shipped rental unit would nearly equal the cost of the new intake. Since the extension is at the top of the penstock, with little pressure, standard 4-inch rubber couplings were initially used to connect the extended penstock. But HDPE is slippery stuff, and the connection became disconnected,

web extras

"Pipeline: Hydro-Electric Penstock Design" by Jerry Ostermeier in *HP125* • **homepower.com/125.56**

"Microhydro Intake Design" by Jerry Ostermeier in **HP124** • **homepower.com/124.68**

"Microhydro Systems: Advice From The Pros" by Ian Woofenden in *HP146* • **homepower.com/146.66**

A new manifold was constructed, switching from rigid to braided PVC, which allows smoother transitions to the turbine nozzles.

A new pressure gauge with HOBO data logger provides monitoring of intake, penstock, and turbine performance.

possibly due to cold weather penstock contraction. Inspired by a Jerry Ostermeier penstock article in *HP125* (see Web Extras), commercial pipe hanger brackets and fabricated steel bars formed a simple but effective brace to secure the joint. After securing the penstock joints, the next weakness was exposed, and the penstock then disconnected from the intake itself thanks to the weight of the now-full pipe. This final joint was reconnected and anchored to the impoundment logs with wire rope to prevent separation.

After years of being peppered with some fine sand and silt that made it through the old homebrew intake, the original runner was worn paper-thin. A new runner was ordered from Harris Hydro and four new nozzles installed (three 3/8-inch and one 5/16-inch). With 100 feet of head behind them, the 3/8-inch nozzles will flow about 28 gpm each; the 5/16-inch nozzle will flow about 19 gpm. So, by turning nozzles on and off, flow-through can be adjusted from 19 gpm to about 103 gpm, depending on the creek's flow. In low-flow conditions, we run two 3/8-inch nozzles, generating about 540 W while keeping the penstock full and pressure up. In high-flow conditions, all four are opened to generate about 850 W. As part of the upgrade, the turbine manifold was also redesigned and replaced. One-inch gate valves replaced the 3/4-inch ball valves. One-inch braided PVC hose made smooth sweeps to the nozzles instead of 90° turns.

Microhydro System Costs

Original System Components	Cost
HDPE 4 in. pipe, 1,300 ft.	$4,250
Xantrex SW4048/S inverter & power panel	4,000
Harris Hydro turbine, 4-nozzle	2,000
4 Deka batteries	2,000
Plumbing, electrical & hardware	1,200
Misc.	1,000
Wire	500
Equipment rental	350
Electrician	300
Air-heater diversion load	250
Xantrex C40 charge controller	150
Total	$16,000
2016 Upgrades	
Hydroscreen Coanda-effect screen	600
Pipe & plumbing to extend penstock & redo manifold	400
New runner	340
Total, with Upgrades	$17,340

Moving Forward

To help determine if the new intake was able to keep the pipe full, we installed a pressure sensor at the bottom of the penstock with an Onset HOBO data logger to monitor pressure at the turbine. Peers have commented that our Hydroscreen installation may be problematic in low-flow conditions, so when that time comes, we plan to add a bit of concrete to the impoundment to prevent the creek from finding small pathways around the Hydroscreen intake. Currently, the new intake is doing a great job at filtering the water for the penstock and at self-cleaning, but the impoundment dam is doing a poor job at guiding all of the creek flow over the intake. Improvements to the dam should enable the farm owners to run the turbine with all four nozzles open and generate full power consistently.

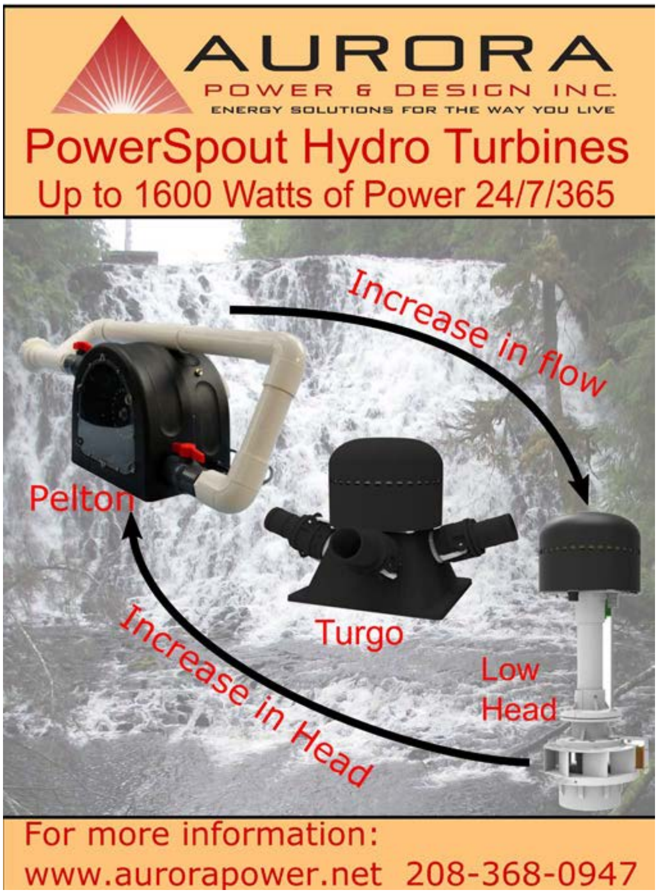
Except for late summer and early fall, when the creek flow is at its lowest, the farm's renewable energy systems are producing more electricity than the homeowners are buying, so they have just been paying the mandatory $30 monthly fee to maintain backup service. In low-flow conditions, the hydro production lags usage and the grid is used as a backup on occasion.

Resources

Harris Hydro • harrishydro.biz • Microhydro turbine

Hydroscreen • hydroscreen.com • Diversion screen

Onset • onsetcomp.com • Data logger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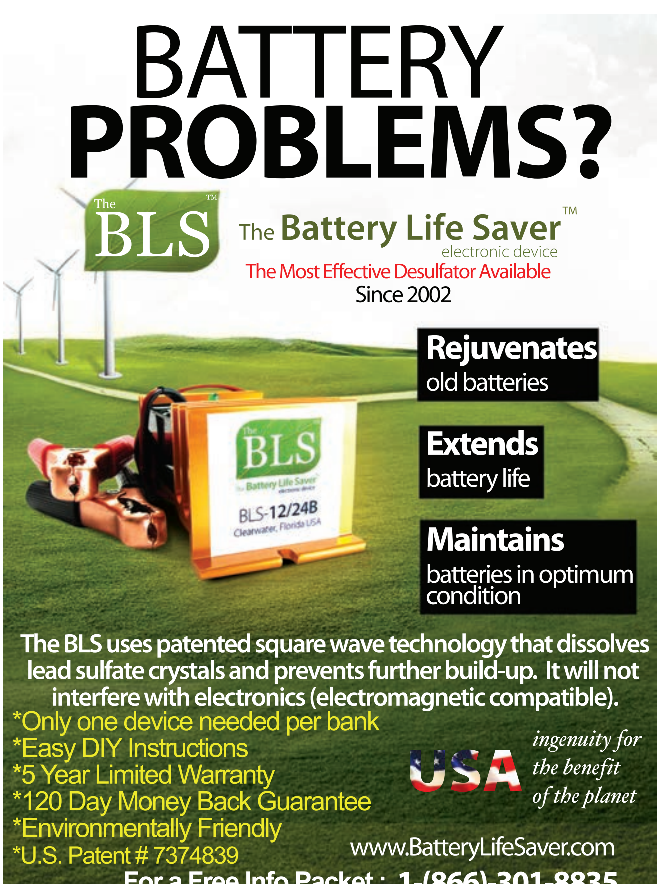
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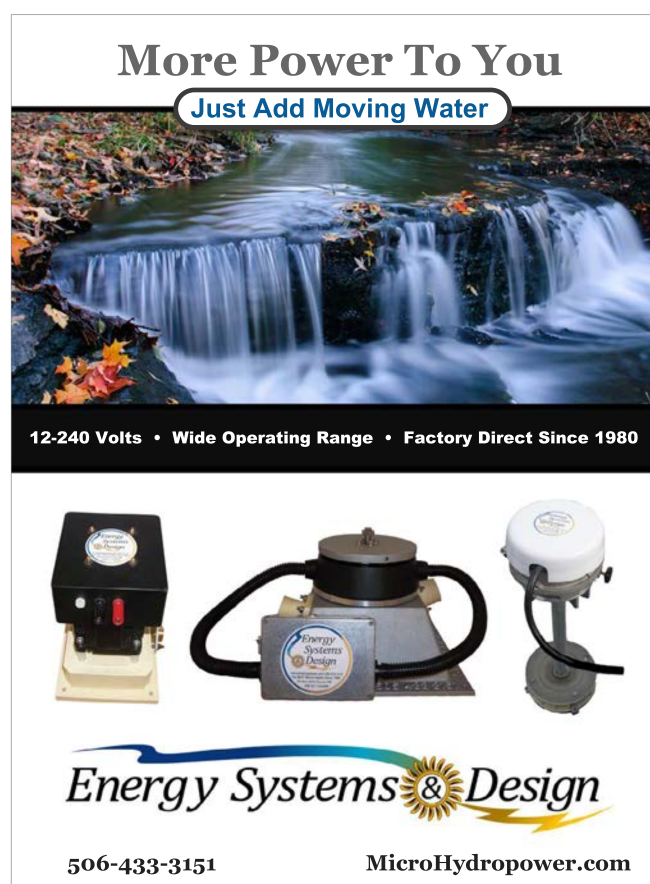
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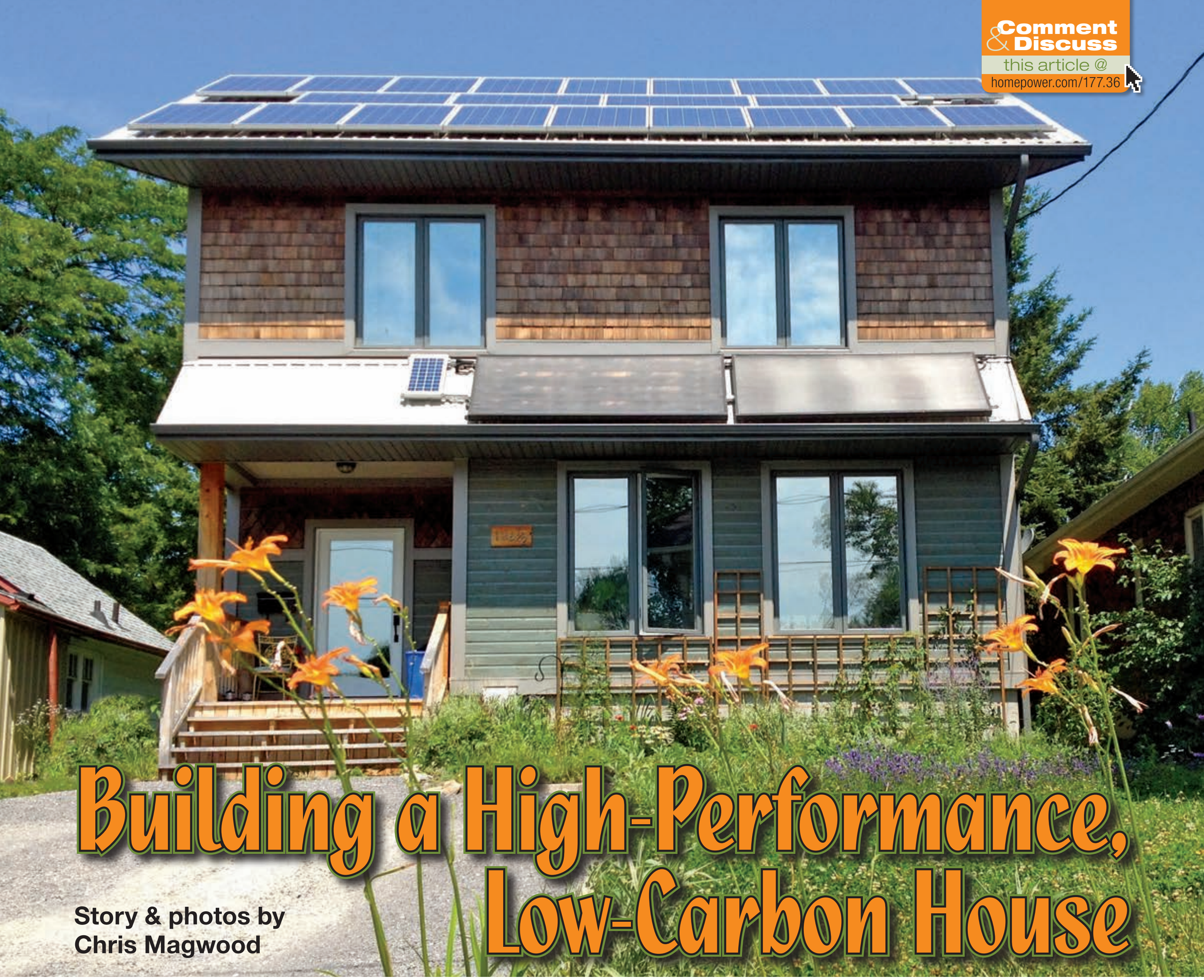


Building a High-Performance, Low-Carbon House

Story & photos by
Chris Magwood

When it comes to reducing emissions that contribute to climate change, the combination of renewable energy and natural building materials offers an affordable, achievable, and effective solution.

A straw bale SIP starts with a structural form and a base layer of plaster.

The base plaster is spread and screeded to a thickness of 1 inch.

Bales are individually "buttered" to adhere to the plaster layer.

Insulating Materials' Carbon Footprints

	Embodied Carbon (kg of CO_2)*		
Insulation	Per kg	Per R-28, 4 by 8 ft. Wall Panel**	After Sequestration (Per Panel)
Straw bale	0.063	8.00	-42.80
Mineral wool batt	1.280	21.75	21.75
Fiberglass batt	1.350	17.60	17.60
Denim batt	1.500	22.45	15.45
Dense-packed cellulose	0.630	41.30	-10.30
Extruded polystyrene foam	3.420	38.50	38.50
Expanded polystyrene foam	3.290	37.25	37.25

* Source: Inventory of Carbon & Energy (ICE) 2.0
**Material densities from *Making Better Buildings*

Reducing construction industry greenhouse gas emissions has focused on the energy efficiency of buildings, by reducing the energy used to heat, cool, and power each building. This focus makes sense, as the energy-related emissions over decades of building use are an obvious target.

However, two critical factors are often overlooked: the emissions of the energy source and the embodied emissions in the building materials—from raw materials extraction to manufacturing. Unlike "fuzzy" targets for energy efficiency—which depend on the quality of construction and occupant behavior for any degree of success—these are measurable factors that can be guaranteed to have the desired effect.

Using renewable energy has immediate and measurable impacts in offsetting carbon dioxide and other greenhouse gases. Less understood is the embodied carbon footprint of building materials, including construction materials intended to decrease energy use. Ironically, high-carbon-emitting materials are often used to save energy and carbon.

Consider the carbon footprint of different insulation materials (see "Materials" table), some of which have a very high carbon footprint. For example, a conventionally constructed, 2,000-square-foot house insulated with fiberglass batts in the walls to achieve R-28 will be responsible for 1,750 pounds of carbon emissions. The same house that uses extruded polystyrene foam insulation in the walls has a carbon tally more than double that, at 3,820 pounds. That home could have been built with straw bale walls, which have a carbon-sequestering effect and would have removed 4,245 pounds of carbon from the atmosphere—where it remains in the home's walls.

Sustainable New Construction students with the finished bale SIP. After drying, the panels are transported to the building site.

Sequestering with Straw

Here's how a construction material can be carbon-sequestering: The cellulose of all plant-based materials is composed of a high percentage of carbon (ranging from 37% to 55%, depending on the plant and the growing conditions). This carbon is "digested" from the atmosphere as the plant grows. When that plant material decomposes (or is burned), most of that carbon returns to the atmosphere. However, when straw or other plant material is used in buildings, it is removed from the atmosphere for decades or even centuries, reducing the overall amount of carbon in the atmosphere.

Bales are squeezed into the form, butter side down.

A top coat of plaster is worked into bales and spread to 1 inch.

The finished surface is screeded and smoothed.

Above: Finished bale SIPs can weigh between 800 and 2,000 pounds and require a crane for moving and placement.

Below: Straw bale SIPs are commonly 4 by 8 feet, but can be custom-sized to fit the envelope design.

The minimal amount of carbon emitted in the straw harvesting and manufacturing is vastly surpassed by the amount sequestered in the material itself. If straw is used instead of foam, the overall effect is 8,065 pounds of carbon reduction for just one 2,000-square-foot home. Multiply that by the 740,000 single-family residences built in the United States in 2015, and that would have been a whopping 3 million tons of carbon reductions.

From Bales to Panels

It looks impressive on paper, but is this a practical suggestion? Isn't straw bale construction slower and more expensive, more of a niche market than a mainstream solution? One answer lies in combining straw bales with prefabricated walls.

My crew and I set out to build a carbon-sequestering home at The Endeavour Centre, a nonprofit sustainable building school in Peterborough, Ontario. Starting with an infill lot in the city center, we wanted to use low-carbon materials and renewable energy to build a low-carbon, net-zero or net-positive energy home. We also wanted the home to be practical and replicable—not a specialty one-off.

A key was to use straw-bale structural insulated panels (S-SIPs) for the walls. Most straw-bale buildings are built by stacking rectangular straw bales like big building blocks, and then applying plaster to the inside and outside faces. Though the materials are affordable, the labor costs can be high, and it can be difficult to find builders skilled in this type of construction. S-SIPs can be built easily by any builder or homeowner, with a fraction of the labor input.

The process starts with construction of a basic wooden frame, lying on the floor. (In this case, we built the walls off-site, but they can also be built on-site.) This box includes sill plates, side frames, and a top plate, which are structural elements of the wall. Using the "wet" method, the box is then filled with 1 inch of plaster before the straw bales are inserted into the wet plaster. They are laid with their length aligned in the direction of the wall, with the strings showing on the interior and exterior faces.

The surfaces of the bales are then plastered with another 1-inch coat, using the top of the frame as a screeding level. In just a couple of steps, the vast amount of the physical labor and time involved in straw bale building are eliminated. Our crew can complete this type of wall in 25% of the time it used to take us to site-build one. The plaster on the walls is allowed to cure, and then the walls are placed on the foundation by boom truck or crane if they've been built off-site, or by tipping them up into place if they've been built on-site. At the time of installation, the bale walls are already protected from the weather; straight and plumb; and ready to have a roof placed on top.

Comparing to a Conventional Canadian Home

	Water Use, 3 Users (L per Day)	Embodied Energy (Megajoules)	Construction Waste (lbs.)
Endeavor House	197	146,437	852
Ontario, Canada, average	675	277,544	8,000
% Reduction	71%	47%	89%

A stem wall of Durisol insulated concrete blocks made from waste wood chips and cement offers lower embodied energy and more sequestered carbon.

To Further Reduce Carbon, We Used:

- Local and sustainably harvested wood for exterior siding, flooring, and ceilings
- Durisol blocks, which use waste wood chips and cement, plus mineral wool inserts, for insulated foundation walls
- Recycled-content expanded glass-bead aggregate insulation (Poraver) mix instead of petrochemical foam below the basement slab
- Blown cellulose insulation in the attic.

Poraver expanded glass bead aggregate provides subfloor insulation without the embodied carbon of polystyrene.

Project Overview

Primary home: 2,702 ft.^{2}; four adults reside in the house

Location: Peterborough, Ontario, Canada

Owner/Designers: Chris Magwood & Jen Feigin

Builder: The Endeavour Centre

Structural engineering: Tim Krahn, Building Alternatives

Cost per square foot: $155 (finished cost—includes design, engineering, and permit fees)

Energy

Passive solar: Home's short side faces south due to lot location and constraints. South windows on both floors are protected by overhangs for passive shading in summer. Passive House modeling software shows 22% of heating needs are met by passive solar gain.

Renewable energy systems: 5.082 kW batteryless grid-tied PV system ($18,000); two solar thermal collectors in closed-loop system ($7,000)

Wall assembly: Prefabricated straw bale SIPs, 16 in. total depth; dense-packed cellulose above and below windows

Water & space heating: Water heating from solar and EcoSmart tankless electric backup. Space heating from Mitsubishi Zuba central air source heat pump. Fully ducted ERV.

Cooling: Overhangs keep out direct summer sun; air-source heat pump can be used for AC, but is used rarely.

Envelope: Met Passive House standards for air-tightness (0.6 ACH), prior to occupancy

Insulation: Durisol block basement (R-28), straw bale SIP walls (R-30), blown cellulose in attic (R-80)

Windows: Triple-glazed, argon-filled, U-0.21 (average) from Inline Windows

Lighting: LEDs only

Water

Municipal water system with rainwater catchment (two 264 gal. tanks)

Blackwater: Received approval for composting toilets, but currently uses low-flush toilets and municipal sewage system

Materials

Wood: FSC-certified or sourced from local mills

Roof: Standing-seam metal

Interior wall finish: Custom-blended clay plasters & clay and lime paints from Kreidezeit

Exterior wall finish: FSC pine siding & locally milled white cedar shingles

Miscellaneous: All nontoxic materials & finishes, Living Building Challenge Red-List approved

Above: Two Thermo Dynamics solar collectors provide all the hot water needed during three seasons.

Right: An EcoSmart electric on-demand heater provides winter backup.

These strategies led to the house being responsible for just 9,920 pounds of carbon emissions for the building shell, compared to four times as much—43,396 pounds—for a typical code-built home, or 56,292 pounds for a home built to Passive House standards using foam insulation. Had we opted to eliminate the basement of the home and use a low-carbon, grade-based foundation, those numbers could have been reduced even further, possibly to the point of overall net carbon sequestration.

Beyond Building—Further Carbon Offsets

The solar water heating system is from Thermo Dynamics, and uses two G Series 4-by-8-foot collectors mounted on the skirt roof that provides shading to the south windows on the home's first floor. A conventional 60-gallon electric water heater tank serves as storage (it is not wired). The water from the tank travels through an on-demand electric water heater on its way to the fixtures. The on-demand unit, an 18 kW EcoSmart reads the incoming water temperature and only adds the amount of power required to meet the output set temperature. For most of the spring, summer, and fall, the auxiliary heater does not turn on at all—the water from the collectors is warm enough for direct use. In the depths of winter when there is little or no solar heat in the storage tank, the unit can keep up with the demands of four adults living in the house. It's capable of providing hot water to two fixtures at the same time, but a third stretches its capabilities. A drain heat-recovery pipe is the final element of the system, helping to preheat the incoming cold water supply to the tank with waste heat that is going down the drain.

Flanagan and Sun designed and installed a 5 kW grid-tied PV system for the house, which offsets about two-thirds of the house's yearly energy use. Limited roof space and economics combined for this decision. The roof-mounted system has twenty-two 231 W modules and a Kaco Blue Planet inverter to feed Ontario's Micro FIT program. The PV system generates about 6,000 kilowatt-hours of energy per year. A contract with Bullfrog Power ensures that any grid energy used comes from renewables, resulting in a zero-carbon footprint for space heating/cooling and other electrical loads. The home's electrical circuits are monitored by a Triacta PowerHawk 4324. For the first two years of occupancy, the consumption averaged 8,867 kWh per year—70% less than the 29,722 kWh average for Ontario homes built after 1996.

Right: Careful air sealing provides 0.6 ACH, meeting Passive House standards.

Below: Even with a narrow south profile, the house is optimized for passive solar gain with adequate glazing and overhangs.

Left & below: A 5,082 W rooftop PV array and a Kaco Blue Planet inverter make a grid-tied system that provides about 70% of yearly energy loads, but still creates a net profit due to the Micro FIT payments for PV-generated energy.

Electrical loads for heating and cooling are kept low thanks to the excellent insulation value of the prefabricated straw bale wall panels (R-30) and a thick layer of blown cellulose insulation in the attic (R-80). Triple-glazed windows from Inline also help to keep temperatures comfortable. The window glazing is "tuned" for each side of the building, with no low-emissivity coatings on the south windows to maximize solar gain. There are double low-e coatings on the inside of the north and east windows to keep heat in the building, and on the exterior side of the glazing on the west, to reflect out unwanted gains. A Mitsubishi Zuba Central air-source heat pump provides supplemental heating and cooling, if needed.

The lot's orientation meant that the narrow side of the building faces south. Still, using the Passive House Planning Package software, we were able to determine the ideal amount of south glazing to maximize wintertime heat gains. The model shows that 22% of the home's overall heating needs are met by passive solar gains, and the real-world numbers appear to confirm that prediction. This is a great example of the value of paying attention to passive solar design even if the situation is less than ideal. With a tight and well-insulated home, any south-facing exposure can provide a valuable contribution. In addition, the careful use of shading from roof overhangs on both floors of the house means that air conditioning (via the Mitsubishi heat pump) has only been used a handful of times, even during heat waves.

To keep other electrical loads as low as possible, we choose our appliances and lighting carefully. Our best investment was an induction cooktop, which uses electromagnetism, rather than resistance, to heat pots and pans. Not only does it use less power to create the heat needed for cooking, but we have come to love the control and immediate response times to changes in temperature settings. The "power boil" feature will have a kettle whistling in no time (2 quarts of water will boil in less than 5 minutes, versus 8 minutes for gas and more than 10 minutes for electric resistance), but the responsiveness of the settings also makes gentle simmers easy to achieve. The unit we bought was an affordable Frigidaire model, so the up-front cost was comparable to a conventional electric range.

PV Array Performance & Payback

2013–2014	PV Production (kWh)	Energy Use (kWh)	FIT Pay Rec'd. (CDN$)	Utility Costs (CDN$)
October	611	155	$330	$33
November	383	501	205	71
December	235	918	124	127
January	97	1,543	48	197
February	155	1,750	80	229
March	332	1,275	176	166
April	652	1,145	353	151
May	621	700	336	99
June	805	292	437	51
July	729	217	395	42
August	781	180	424	38
September	674	191	365	38
Totals	6,075	8,867	$3,273	$1,242
Net Energy	-2,792			
			Net Profit	$2,031

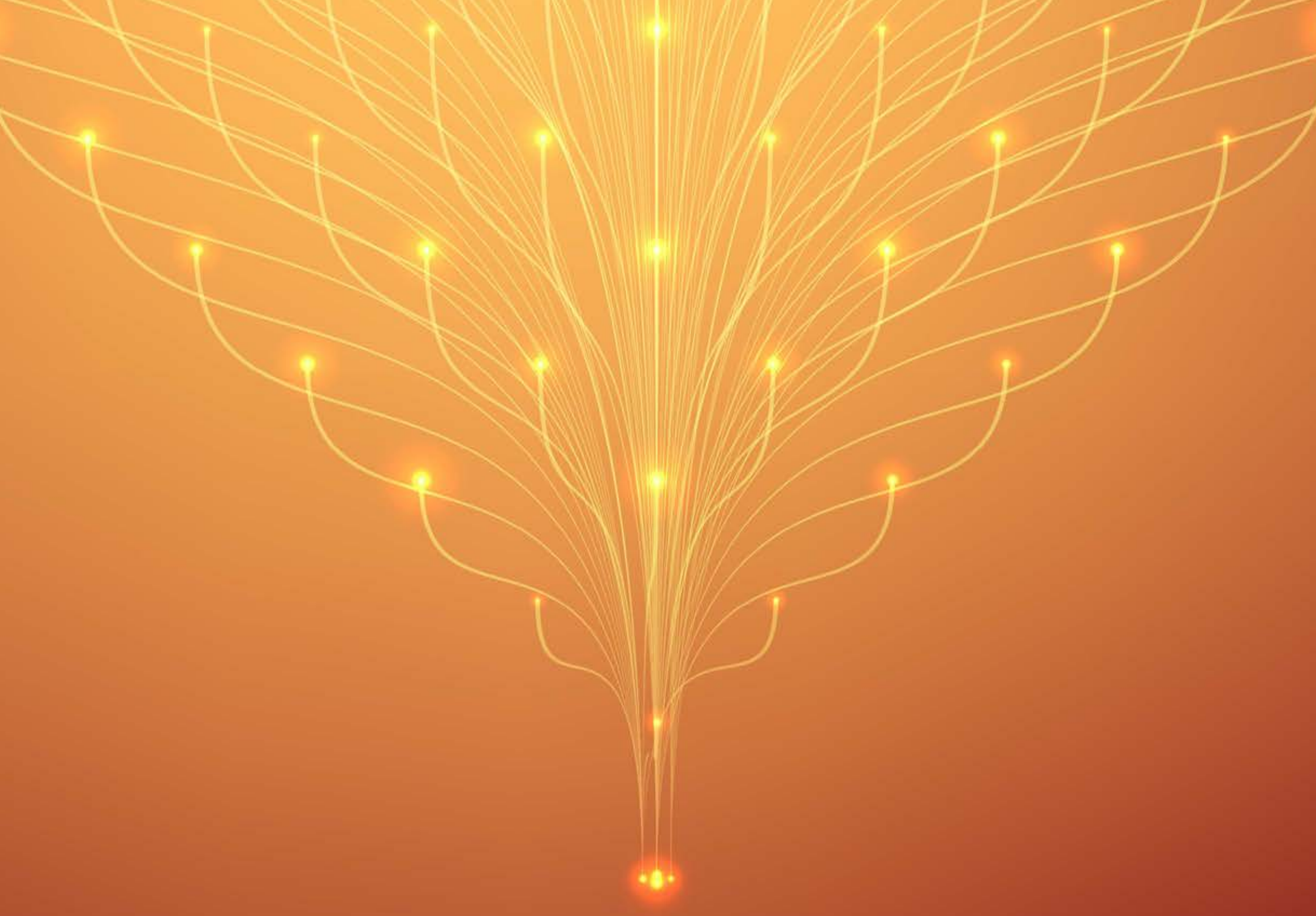
An induction range cooks using electricity—without wasting heat.

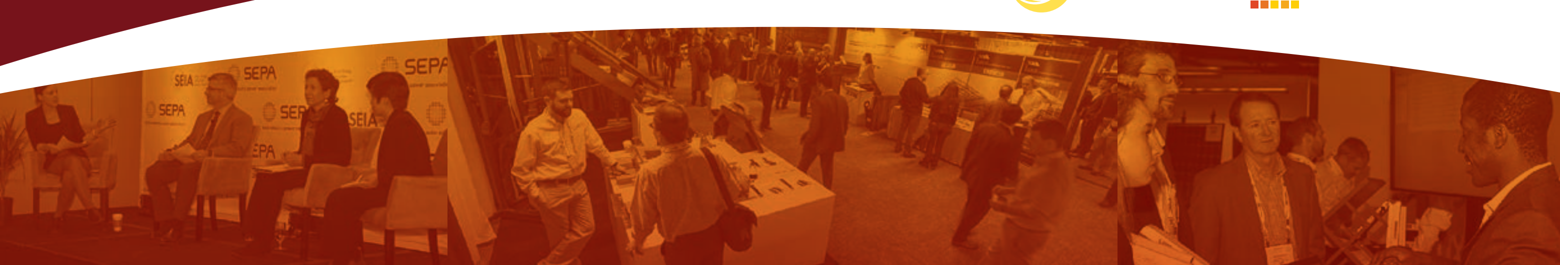
Custom-blended clay plasters, and clay and lime paints are some of the natural, nontoxic materials that were used throughout construction.

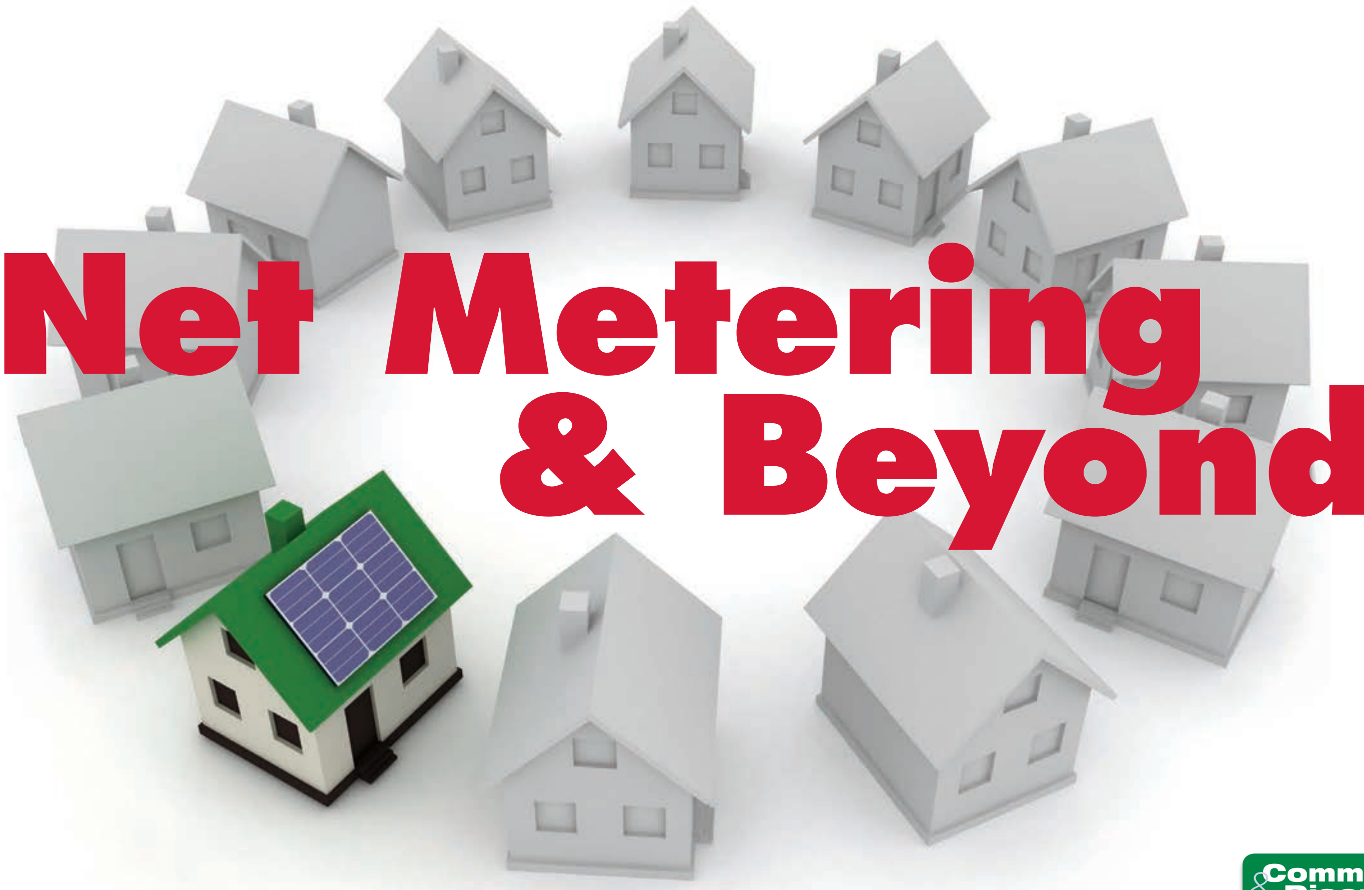
LED lighting is used throughout the house. Appliances were purchased using EnergGuide ratings to buy the most efficient models in an affordable price range. There is no clothes dryer; instead, a convenient two-tiered hanging rack sits near the washing machine and the main HRV return duct ensures that moisture levels stay at appropriate levels in the house.

The home earns an average of $2,000 each year above all utility costs, thanks to the Micro FIT purchasing rate of $0.54 per kWh. A home that is a net earner rather than a net expender is a rare thing, and makes for a compelling financial scenario. Reinvested in the home mortgage, this solar income can reduce a typical 25-year mortgage to 16.5 years.

The Endeavour Centre home is an example of how renewable energy systems and low-carbon building materials can combine to provide a zero carbon house, without sacrificing cost or comfort. These solutions are within our collective reach, and only require a willingness to provide immediate solutions to climate change, affordability, helping local economies, and providing occupant health and safety.







Net Metering & Beyond

by Christopher Freitas & Carol Weis

For grid-tied PV system owners, net metering has been a popular way to credit homeowners for the surplus energy their systems produce. Net metering, together with monetary incentives and state PV energy target levels, makes it easy to connect PV systems to the grid and has resulted in the high growth of residential PV systems.

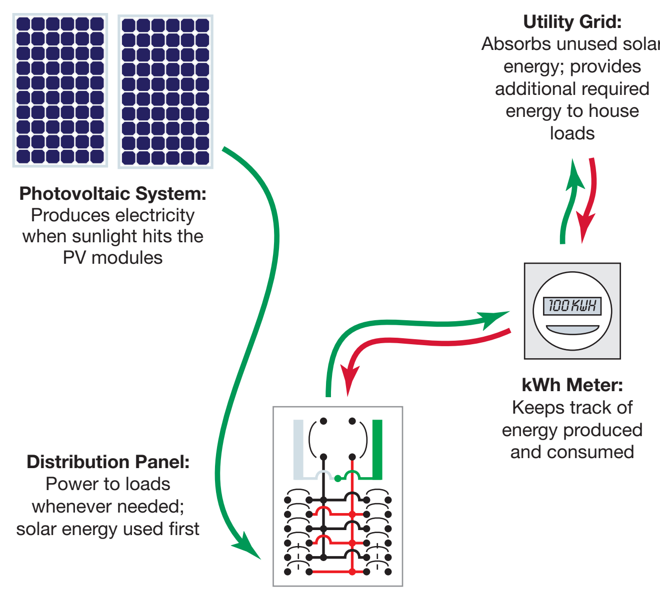
But this popular policy has recently been under attack and the resulting changes will have serious implications for the solar industry and future PV system owners. This article highlights what changes are occurring, their ramifications on the solar industry, and how to approach PV system design if these changes come to your area.

Net-Metering Basics

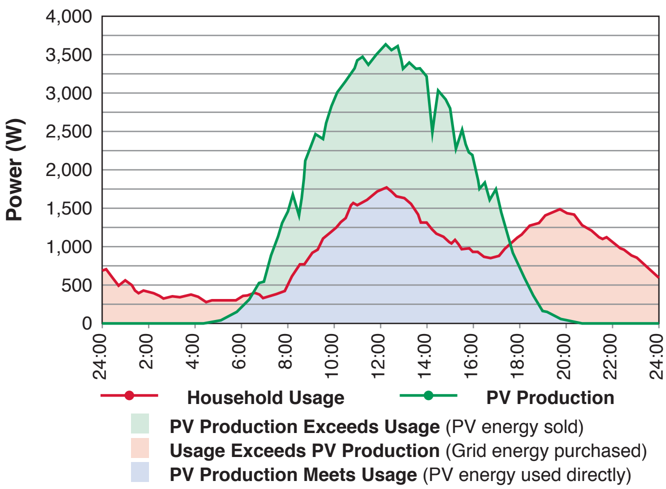
Under net metering, when a grid-tied PV system's output is greater than the building's electrical consumption, that excess energy flows through a kWh meter into the utility grid. The monetary value of the energy is counted and accumulates as credit, which can be used when the loads are higher and PV system output is lower or nil, such as at night or during cloudy weather. Most utilities allow credits to be carried over from month to month, which allows homeowners to draw on summer's "banked" electricity during the winter months, when system production tends to be lower.

According to the Solar Energy Industries Association (SEIA), in a typical residential net-metered solar installation, only 20% to 40% of the energy produced by the PV system is exported to the grid—most of the energy produced is used directly in the home. Customers are only billed for their net energy use—that is, the electricity they use at home beyond their PV system's production and beyond any accrued credits. Surplus PV electricity is usually consumed close by, reducing the load on the utility grid, reducing transmission and distribution losses, and reducing emissions and pollution from power plants.

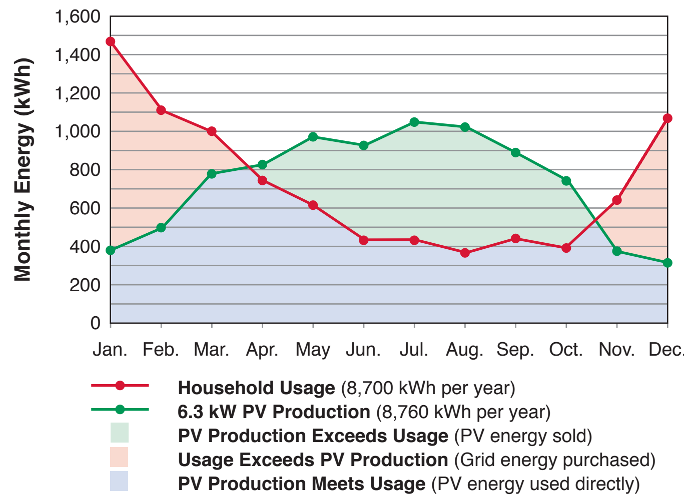
The Flow of Net-Metered PV Energy



Example Daily PV Production vs. Loads



Example Seasonal PV Production vs. Loads



Net metering offers a simple, low-cost way to accommodate and encourage the installation of grid-tied PV systems. Typically, a single kWh meter can be used, instead of requiring an additional kWh meter for the PV system. A key concept of net metering is that the customer buys electricity from the utility and sells back their PV-produced electricity at the current utility rate. Some utilities also combine net metering with time-of-use (TOU) rates—if the excess electricity is produced during peak rate periods, it is credited at this higher rate, therefore offsetting the cost of more kWh consumed during off-peak periods, which are priced at a lower rate.

Net metering has helped encourage the rapid growth in "distributed" PV systems, which provide other benefits. Distributed PV systems produce nonpolluting energy close to the points of consumption and the systems' production often coincides with peak demand occurrences, such as air-conditioning on a hot, sunny summer day. This supply of peak power is much less expensive than buying it on the utility power exchanges or building new plants to meet this demand.

According to the Database of State Incentives for Renewables and Efficiency (DSIRE, dsireusa.org), as of July 2016, 41 states had mandatory net-metering rules. Two states do not have mandatory rules, but have utilities that allow net metering (Idaho and Texas); four states have statewide compensation rules other than net metering (Georgia, Hawaii, Mississippi, and Nevada); and three states have no net metering in place (Alabama, South Dakota, and Tennessee).

Challenges to Net-Metering Laws

Recently, net-metering laws have been challenged in several states. Several utilities argue that changes are necessary because they feel customers with grid-tied PV systems are not paying their fair share to maintain the electric grid and to pay for the utility's fixed costs and overhead since some of the fixed costs are built into the per-kWh energy charge. Utilities say that this is forcing those without PV systems to pay more to make up for the loss of revenue from the PV systems.

Some utilities also argue that as the amount of PV-generated energy on the grid increases, the unpredictable nature of distributed energy systems will cause problems with the grid's operation, requiring upgrades to the distribution and transmission lines and the control and protection systems—and insist that these upgrades are not being paid for by the solar-powered customers.

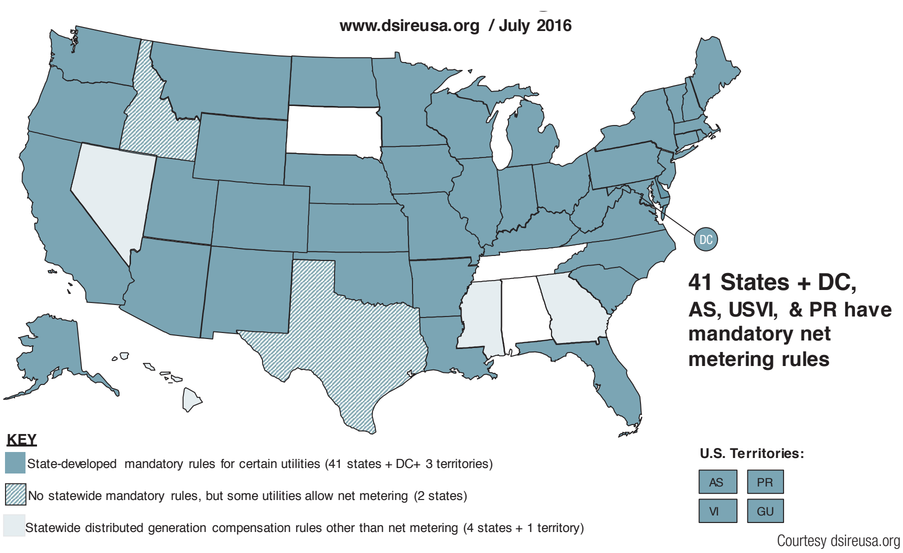
As more and more PV systems contribute to utility energy, utilities argue that they still need to keep generator capacity standing by (called "spinning reserves") due to the intermittent nature of PV electricity. For instance, even though on a typical day there could be a large amount of solar electricity capacity, if it becomes cloudy in the middle of the afternoon, the utility would need spinning reserves to instantly provide power to all grid loads until the sun returns.

Here are some of the recent state-level changes—coupled with the impact the changes are having on the solar industry in these regions:

Justine Sanchez

Most modern kWh meters will record in both directions (energy export and import), but "net metering" is an agreement with the utility of the cost/credit value of those kWh.

Net Metering Regulations by State



Courtesy dsireusa.org

Hawaii. In October 2015, the Hawaii Public Utility Commission (HPUC) ended its net-metering program. Although the HPUC admitted that net metering had been successful and instrumental in helping Hawaii make progress toward the goal of 100% renewable energy, they say that changes were made to the net-metering program to "address new issues and challenges."

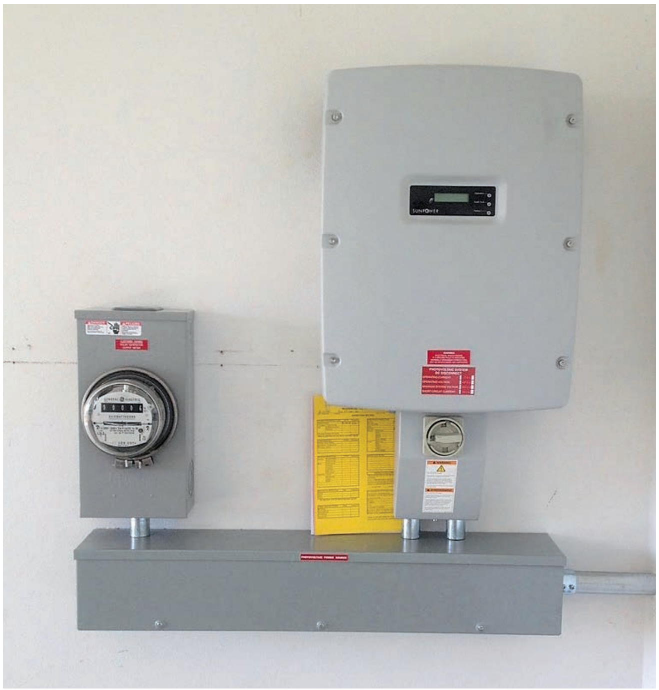
Moving forward with its Phase 1 Decision, the HPUC created different approaches that grid-tied PV system owners can choose from, including a "self-supply" system and a "grid-supply" system. The "self-supply" system does not export power to the grid but only supplies what is used in the residence. The "grid-supply" system can export power to the grid, but the exported energy is compensated at a reduced rate and there is an overall cap for each island, limiting the total capacity of grid-supplied systems. As of October 2016, the Hawaii Solar Energy Association (HSEA) stated that this cap was already met on all islands and thus no further grid-supply systems can be permitted. HSEA also reported that the new rules have resulted in a 42% reduction in solar-related jobs since October 2015.

Nevada has been a closely watched battleground for net metering. In a highly contested decision issued in December 2015, regulators from the Public Utilities Commission of Nevada (PUCN) revised net-metering rules to compensate at the utility's wholesale rate—instead of at the retail rate—for PV electricity exported to the grid, and they increased the monthly fixed charges for grid-tied PV systems. This ruling was not only for new PV systems, but for existing systems as well. However, in September 2016, according to Vote Solar, the PUCN reversed its earlier decision by grandfathering-in existing PV systems, allowing some 32,000 system owners to once again receive full compensation for the surplus energy their systems supply to the grid. The revised decision by the PUCN does not change the new fixed fee structure that requires that residential PV system owners pay a higher monthly fee (increased immediately from \$12.75 to \$17.90, and eventually reaching \$38.51 by 2028). For new grid-connected PV installations, the rate paid per kWh for exported energy was reduced from \$0.113 to \$0.092, and will continue to drop every three years until it will be \$0.026 by 2028.

Colorado. In early 2016, Colorado utility Xcel Energy proposed a new rate structure that increased the fixed monthly charge and decreased the per-kWh credit. Greentech Media reported that the new rate structures were implemented by the utility because they wanted to allow fair treatment of all ratepayers and they wanted grid-tied PV systems owners to cover their cost for using the grid.

Later that summer, the Colorado Solar Energy Association (CoSEIA) announced that a settlement agreement had been reached between CoSEIA, Xcel Energy, and 24 additional organizations. Under the new agreement, net metering was continued and the proposed new rate structure was dropped in exchange for a trial program based on residential TOU rates, as seen in the "Proposed Rates" table. TOU programs encourage consumers to reduce their usage during peak consumption periods by charging higher rates at those times. Because peak demand can coincide with PV production, this type of rate structure and compensation can economically benefit grid-tied PV system owners. Initially, residential customers will be able to opt in to the proposed TOU program. If the program is deemed successful, it will become the default rate program after 2020.

The component simplicity and lower cost of a batteryless grid-tied PV system makes it the most common solution for distributing clean energy to the grid.



Courtesy True South Solar

Proposed Colorado TOU Rates

Category	Times	Rate (Per kWh) Summer	Rate (Per kWh) Winter
On peak	2 – 6 p.m. (weekday, non-holiday)	$0.13814	$0.08880
Off peak	9 p.m. – 9 a.m.	$0.04440	$0.04440
Shoulder	All other times	$0.08420	$0.05413

Net Metering?

Many utilities have changed the rules for their net-metering programs, switching from paying an equal retail rate for the PV energy exported to the grid to paying a much-lower wholesale rate for exported solar energy. Several of the utilities, such as those in Nevada, are still referring to these new programs as "net metering"—but is it?

The typical definition of net metering always had the credit and charge for each kWh as equal amounts. Using this same term for the new, less advantageous reduced-compensation rate programs seems inappropriate and misleads the consumer—it allows the utility to say that its net-metering program has just been modified instead of obliterated.

For grid-tied PV systems greater than 10 kW, a couple of utilities, such as IID and PNM in New Mexico, have changed the name of their net-metering programs to "net billing" to indicate the lower exchange rate—but this can still cause confusion because the RE industry has often used the two terms "net metering" and "net billing" interchangeably.

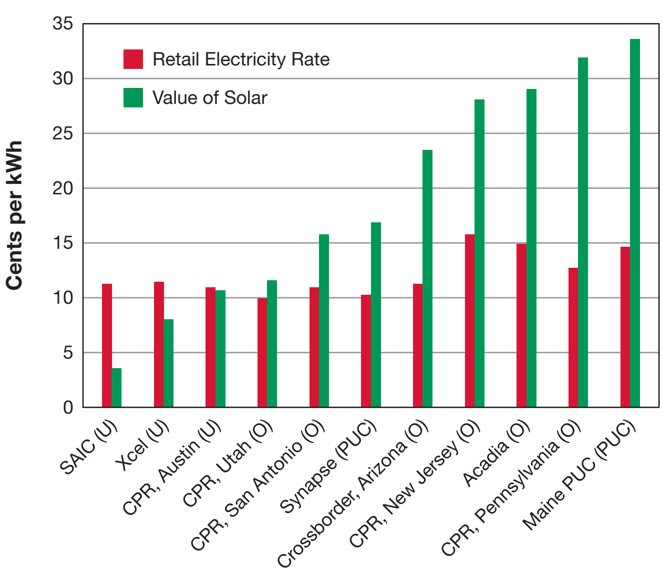
Arizona. In May 2015, Arizona's small private utility, UNS Electric, proposed decreasing the exported PV energy rates; increasing their fixed monthly PV system fee from $10 to $15; and adding a peak power demand charge for all customers. Two of the larger regional utilities, Tucson Electric Power and Arizona Public Services, were also considering making similar changes to their rate structures.

In August 2016, the Arizona Corporation Commission (ACC), the utility regulatory body, decided to accept the fixed fee increase but postponed the kWh rate change until a study on the value of solar electricity was completed—with the determination to be made by early 2017. The decision also included amendments to preserve net metering for customers with existing PV installations.

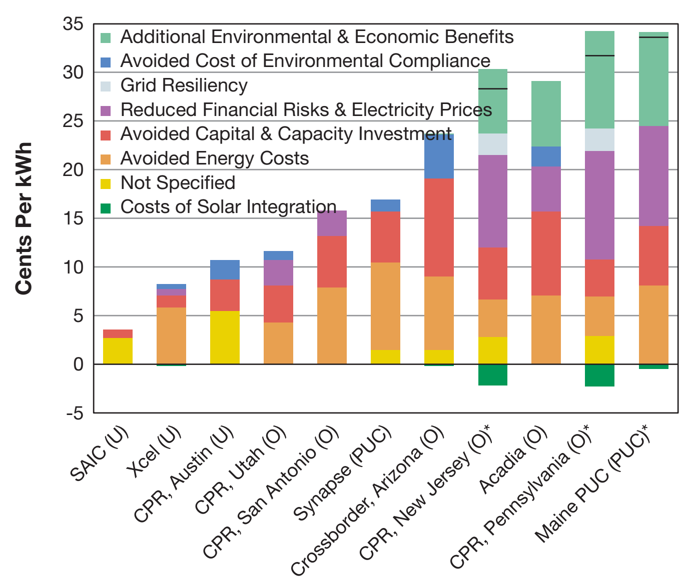
California. In California, Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric proposed to the California Public Utilities Commission (CPUC) a new rate structure that reduced the net-metering compensation for all grid-connected PV customers. In January 2016, the CPUC denied this proposal. The utilities appealed, but the CPUC upheld the previous decision, stating that the utilities did not provide adequate evidence of cost shifting being caused by net metering, and that the other benefits provided by PV systems, such as reductions in power plant emissions and pollution, as well as jobs and economic development, needed to be included in their calculations.

Meanwhile, another southern California municipal utility, the Imperial Irrigation District (IID)—which is not regulated by the CPUC—closed its net-metering program and switched to what they have renamed a "net billing" program. The new program does not compensate the solar producer at the retail level but instead pays a lower wholesale rate for the power exported to the grid. Those customers with PV systems installed prior to July 2016 will continue with the previous net-metering program.

Electricity Rates & Values of Solar Energy



Cost-Benefit Analyses by Study & Category



(U) Studies written or commissioned by utilities; (O) studies written or commissioned by non-utility organizations; (PUC) studies written or commissioned by public utilities commissions. *Lines indicate the value of solar energy as calculated in the analysis.

Courtesy "Shining Rewards, The Value of Rooftop Solar Power for Consumers and Society," Environment America Research & Policy Center (2)

Value of Net Metering

Multiple investigations into the impact of net-metered PV systems have shown that solar electricity benefits both the utility and its non-solar customers. For example, in "*Rooftop Solar: Net-Metering is a Net Benefit*," Washington, DC think-tank The Brookings Institution showed that net-metering nearly always provides non-solar ratepayers and the utility with economic benefits that exceed the costs of the programs for grid-connected PV system owners. The report also concluded that grid-connected PV systems do not result in any significant cost-shifting to the general ratepayers.

A 2016 study by the independent consulting firm Crossborder Energy found that, in Maine, distributed PV systems helped reduced the price of electricity for all ratepayers by lowering the demand during daytime peak periods. Based on this study, the Natural Resources Council of Maine states that the 20 megawatts (MW) of grid-connected PV capacity already installed results in a savings of $45 million for non-solar utility customers. The resultant economic value of reduced pollution from power plants is valued at an additional $58 million. In areas of the United States that have better solar resources, higher utility costs, and fewer low-carbon energy sources (such as hydro and biomass), the overall benefits of net-metered PV systems are even greater.

Accommodating New Policies

For states with high utility rates, PV-generated electricity can still make good economic sense—even without net metering—if the system is designed to maximize self-consumption of the renewable energy produced. "Smart"

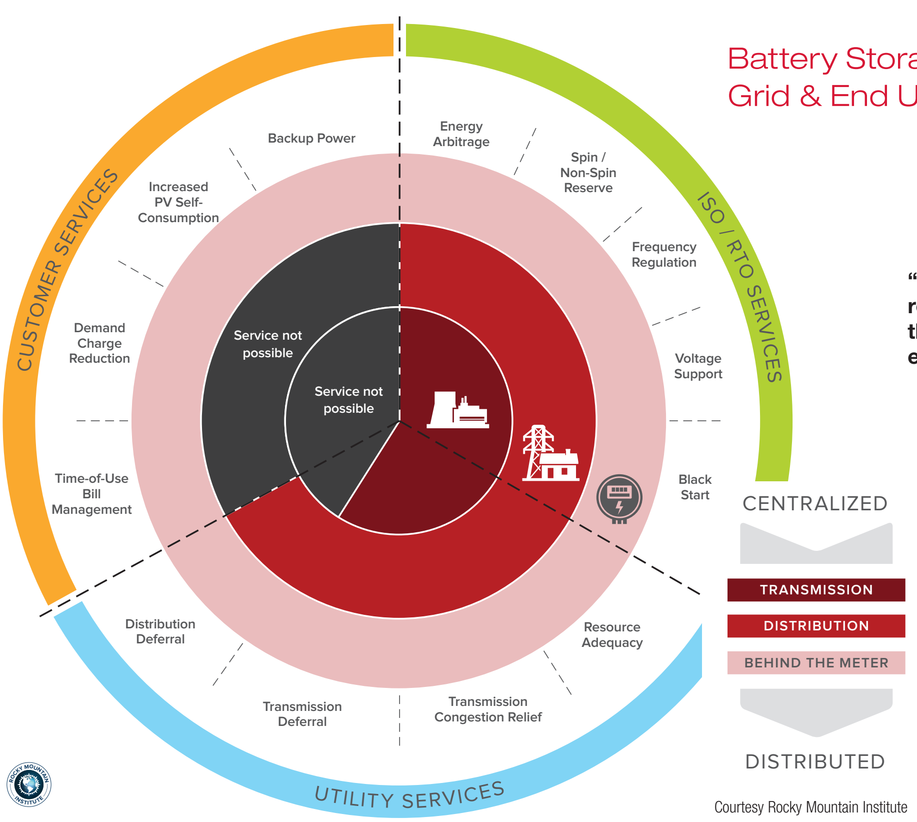
Impacts of Eliminating Net Metering

The effects of ending net-metering programs are not limited to utilities, system owners, and utility ratepayers. These effects are also real:

- **Loss of existing jobs and decline in the growth of new solar jobs.** The elimination of net-metering programs in Hawaii and Nevada has already resulted in a substantial reduction in the amount of PV being installed, plus caused large layoffs of solar workers. A year after the decision to end the net-metering program, the Hawaii Solar Energy Association stated a reduction in solar jobs of 42% and a decrease in new permits by 27.3%.
- **Reduced economic advantage.** The reduced value of each kWh of PV-generated energy that is exported to the grid, combined with the higher fixed fees charged by the utilities, makes the economics of grid-connected solar less attractive to the homeowner. This type of rate structure discourages PV installations, and can also serve to stymie energy conservation efforts.
- **Less solar investment.** The uncertainty felt by solar investors, who are concerned about the possibilities of future retroactive changes and additional fixed fees, has a significant impact on other regions that are watching the utilities' policy shifts.
- **Additional pollution.** Less solar capacity will require more generation of fossil-fuel-generated electricity by utilities, resulting in more pollution and carbon dioxide emissions.

Battery Storage Benefits: Grid & End User

"The Economics of Battery Energy Storage" report by the Rocky Mountain Institute shows that battery storage systems can benefit both end users and utilities alike.



Courtesy Rocky Mountain Institute

Courtesy JLM Energy

JLM Energy's Energizr 200 energy storage system with Loadz appliance interface offers lithium iron phosphate battery storage and the ability to control household loads for energy management strategies.

energy management systems, which are new to the U.S. market, can control large appliance loads (like air-conditioners, water heaters, pool pumps, etc.) to coordinate their operation to better match the PV system's production. This reduces the amount of energy which is fed back to the utility grid, and maximizes the amount of solar energy consumed by the home, achieving a better economic return on the solar investment.

In regions where net-metering programs are unavailable, pairing inverters with advanced energy-storage systems can also improve the economics of grid-connected PV systems. Any surplus energy produced by the PV system can be stored in a battery bank for later use—when loads are high or when the PV production is low. Batteries with longer lives and higher performance, and higher-efficiency inverters, are making this option more attractive and offer the potential to lower the overall lifetime cost of battery-based PV systems.

Matching the loads to the PV production profile and using energy storage to meet loads later in the day also reduces the impact that high solar capacity can have on a utility's grid distribution and transmission systems. Both can allow the utility to reduce the amount of spinning reserves required to keep the grid stable, allowing for significant cost savings and reduced emissions/pollution levels. There are additional benefits as well; the Rocky Mountain Institute's "The Economics of Battery Storage" report shows that battery storage systems can provide 13 different services to three different stakeholder groups (as seen in the graphic).

Energy storage systems can work with the utility grid to supply energy during periods of high load levels, such as late afternoon of summer months when people return home from work, turn on their air-conditioners, and start cooking dinner on electric stoves. The latest generation of energy storage systems is being designed to receive a signal from the utility during periods of high demand to feed the PV production and stored energy back onto the utility grid. How the system owner would be compensated by the utilities for this assistance is still uncertain, but this idea is already being utilized in other parts of the world—such as in some regions in Australia, where PV installations are on 40% of homes.

Be Active

Changes to net-metering policies can have a significant economic impact on PV system owners and the solar energy industry. It is important to stay informed of any proposed changes and participate in the development of new rate structures. Ensuring that both solar and non-solar ratepayers are treated fairly is important, but the analysis needs to incorporate all of the costs and benefits involved.

With the emergence of new technologies, such as energy storage and advanced system management, policies will have to be adjusted to allow reasonable returns on investments made both by the utilities and by the solar-equipped consumer. Allowing the solar industry to be throttled back by the adoption of short-sighted policies and utility self-interest at this critical point in time would truly be a failure.

Resources

"Shining Rewards, The Value of Rooftop Solar Power for Consumers and Society," Environment America Research & Policy Center • **environmentamerica.org/reports/amc/shining-rewards**

"Rooftop Solar: Net-Metering is a Net Benefit," The Brookings Institution • **brookings.edu/research/rooftop-solar-net-metering-is-a-net-benefit/**

"Initial Update of the Maine PUC's Value of Solar Study," Crossborder Energy • **nrcm.org/wp-content/uploads/2016/08/ValueofSolarstudyUpdate.pdf**

"Study Shows Solar Saves Money for All Ratepayers in Maine by Reducing Peak Demand," Natural Resources Council of Maine • **nrcm.org/news/nrcm-news-releases/study-shows-solar-saves-money-ratepayers-maine-reducing-peak-demand/**

"The Economics of Battery Energy Storage," Rocky Mountain Institute • **rmi.org/electricity_battery_value**

Off-Grid Water Heating

by Ian Woofenden & Vaughan Woodruff

In North American homes, heating domestic water for bathing, dishwashing, and other related tasks is typically the second largest load (space heating and cooling is usually first), consuming 15% to 25% of the energy a home uses. About half of this is in the bathroom, a third in the laundry, and the rest is in the kitchen. Many grid-tied homes rely on electric resistance water heaters, but this is not a viable option for most off-grid homes.

It's important to ask first what your motivations and preferences are around domestic hot water, and also some specifics of your situation. If your primary motivation is low cost, you may come up with a different solution than if your primary motivation is using renewable energy. Reliability, serviceability, capacity, convenience, and other factors will play into your decision.

Then, you'll need to identify what fuels and resources are available to you. Your water "load" and your access to sunshine, space for tanks, as well as your budget and abilities as a plumber may affect your decisions as well.

Conservation & Efficiency First

When it comes to heating water, it's sensible to start with not only energy efficiency but also water efficiency. Using low-flow fixtures should be the first step—they use less water to do the same job. Low-flow showerheads, for example, provide a flow of less than 2.5 gallons per minute (gpm). Laminar (non-aerating) heads provide more accurate temperature control, while aerating creates more steam and moisture. Low-flow sink faucets have a flow of less than 1.5 gpm. After-market flow restrictors or aerators can usually be added inexpensively.

Low-flow fixtures save water and save the energy needed to heat water. Water-saving appliances like clothes washers and dishwashers are also important in reducing the overall water-heating load. Horizontal-axis washers and high-efficiency dishwashers typically use less water, and choosing appropriate settings on all water-using appliances also helps use less hot water. For example, choosing to wash most of your clothes in cold water, rather than warm or hot, can provide significant energy savings. Buying a horizontal-axis machine that's sized appropriately for your household will also ensure that you're using every gallon of heated water efficiently. Make sure you skip any washers that use steam to wash or electric elements to "boost" the temperature, since these will tax your RE system. Dishwashers pose similar issues, so select them carefully.

Inefficiency in heating applications manifests primarily as heat loss. Choose a heating method that is inherently efficient and effective—but keep the heat in once you've made it. Super-insulated tanks, thoroughly insulating hot water pipes, and either installing tanks with heat traps integrated into their fittings or installing a gravity heat trap in the tank piping will minimize standby heat loss. These strategies will also allow lower temperature settings by minimizing the difference between the tank and the fixture temperatures. If there's a recirculation system involved, managing it carefully with wise plumbing and timer use is important, too.

The bottom line is to use only as much water as you need to get the job done. Heat it intelligently and don't lose any more of that heat than is absolutely necessary.

©istockphoto.com/ jordieasy; Difydave; BanksPhotos

Efficiency measures that save water, as well as heat, are the first step in meeting off-grid hot water needs without breaking the bank.

Climate Considerations

In cold climates, selecting the water heater type is typically not an isolated decision. Since space-heating loads often represent the greatest share of energy, integrating water heating with space-heating tends to be the most cost-effective and simple solution. For example, if you install a propane boiler for space heating, you will likely also use the boiler to heat domestic water by installing an indirect water heater or by installing an add-on option to a wall-hung boiler that allows the boiler to also provide instantaneous domestic water heating. In warm climates, domestic water heating may be accomplished with a simple stand-alone appliance.

Solar Thermal

A solar water heating (SWH) system uses solar collectors to absorb the sun's energy and transfer that heat to water. The solar energy it collects reduces the need for other energy sources for heating water. In off-grid systems, this often results in reducing propane consumption.

The simplest are direct systems—those that directly heat potable water in the solar collector—that can be used in climates where the collectors are not exposed to freezing. Indirect systems are used in freezing climates, and separate the potable water from a freeze-protected heat-transfer fluid by using a heat exchanger.

Batch water heaters, also referred to as integral collector storage (ICS), are the simplest type of direct solar water heating system. They heat a stored volume of water directly in the collector. Simple batch systems can be constructed from an old water heater tank that is stripped of its insulation, painted black, and encased in a glass-topped insulated box.

Direct recirculation SWH systems are an option in warm climates or for seasonal water heating. These systems use a stainless steel or bronze pump to circulate potable water between a tank-type water heater and a solar collector. The circulator pump is controlled by a differential controller that monitors system temperatures. A small PV module can be used to generate the electricity.

In freezing climates, antifreeze SWH systems are common. Antifreeze systems can use circulators with low electrical draw because the heat-transfer fluid is in a closed loop. Another type of freeze-protected SWH system, a drainback system, can require two to three times more electricity for a standard residential system because it requires the pump to lift water to the collectors. This uses more energy than a circulator that simply needs to circulate fluid without lifting it.

Unless you are willing to live with hot water only when there is sufficient solar energy, the selection of a SWH system is heavily dependent upon how it will integrate with its backup heat source.

A solar thermal system is one option worth considering. System types vary with climate, needs, and budget. See the "Resources" sidebar (page 56) for links to more information.

Vaughan Woodruff

Ian Woofenden

Solar & Wind Electricity

For off-grid homes, electricity is usually not an ideal source for heating water, since the loads are so large. However, PV module prices have dropped significantly recently, so some people have been experimenting with solar electricity for water heating—including directly connected to electric-resistance tank-style water heaters (see "PV-Direct Water Heating" sidebar).

One simple way that an off-grid system can provide some water heating is via a "dump" or diversion load. Most PV systems simply turn off the array when the batteries reach a full state of charge, and most wind and hydro systems need to be kept fully loaded, and therefore need a "diversion" controller and dump load. This can divert excess solar energy to an air or water heater.

Two drawbacks emerge from this diversion strategy: (1) It usually isn't enough energy to meet all of your water heating needs. This means you'll need backup, and it will need to work with the diversion system. (2) A wind or hydro turbine dump load must be able to absorb all of the system's capacity in times of low or no loads, and a domestic water tank may get too hot to absorb all the energy. Water tanks are not ideal as the sole diversion load for excess wind or hydro energy.

PV-Direct Water Heating

It has been my experience that domestic water can be heated economically using PV-generated electricity. Five years ago, this would have been foolish, but monocrystalline PV modules can now be purchased for less than $1 per watt. For $2,000, you could have 2,000 watts and produce a lot of hot water—about 10 gallons per peak sun-hour.

A PV array can be directly connected to the electric resistance-heating element in the bottom of an off-the-shelf, tank-style electric water heater. It's possible to run a 240-volt AC water heater on DC, avoiding an inverter or batteries. Resistance heating elements run identically, whether on AC or DC. Silicon is cheap and copper for solar thermal water heating is not so cheap. The cost per watt of energy sourced from PV modules or from a solar thermal collector is almost equal—but PV modules are easier to install, more reliable, and simpler than an SWH system.

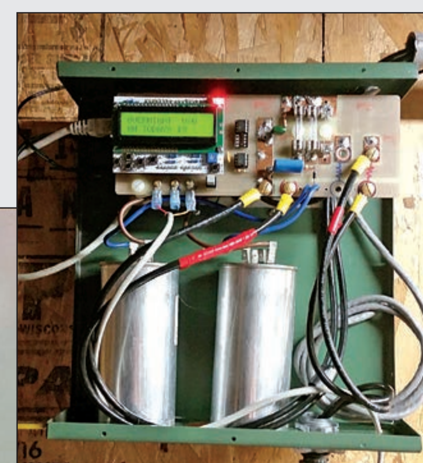
This strategy has been working for me for the past 16 months. I have 1.2 kW of PV devoted to heating domestic water. My well produces 55°F water, but I like it heated to 130°F, which my system provides almost all of the time.

—Pete Gruendeman

Hugh Piggott

Pete Gruendeman

With the lower cost of PV modules, heating water with solar electricity is now a reality, whether you choose part-time diversion (right); part of a whole-house system (below); or PV-direct (far right).



Pete's custom controller (right) and its connection to an electric water heater (below).

Pete Gruendeman (2)

In larger off-grid homes with backup generators, a conventional electric tank, a heat pump, or on-demand water heaters *could* be used. But careful analysis of the actual energy load and resources is in order, because heating water could result in heavy use of the generator and the need to upsize your inverter, which may be questionable on practical, convenience, environmental, and financial grounds.

Wood

Wood is a renewable fuel, and can be a clean and plentiful fuel if harvested and burned with care. Many off-grid homes have access to wood, and there are many opportunities for salvage, gleaning, and sustainable harvest of wood products.

Heating domestic water with wood can take several forms, with varying convenience and complexity. Boiler systems—which have a large firebox, sometimes outside the home—heat water for space heating as well as domestic use. These can be custom-made or manufactured. Some of these systems can take very large and long pieces of wood, reducing processing time.

A common method for wood water heating uses a metal coil (exchanger) inside a wood stove. This often takes the form of a single loop in the side or top of the firebox. Water is plumbed from a tank to feed this loop, which is exposed to high temperatures when the wood heater is operating. These loops are often set up as thermosiphons, with the tank somewhere above the level of the heater and the plumbing running all uphill/downhill, with no pockets to inhibit the natural flow. These systems can produce dangerously high-pressure, high-temperature steam, so precautions must be taken to avoid airlocks, and to include temperature and pressure-relief valves in appropriate places.

Some cookstoves include coils, but may have a "reservoir"—an unpressurized vessel built into one end of the stove. This is fairly inconvenient, since it requires dipping hot water out of the reservoir for use. Similarly rudimentary is heating water in pots on the top of wood heaters—a practice experienced by lots of pioneers.

Water "in" and "out" temperature gauges (right) on the hydronic loop of a wood-fired cookstove (below).

Ian Woofenden (2)

Wood, Solar & Propane

During the heating season, when wood is being burned, solar energy is typically less available. Conversely, during months when you would want to avoid burning wood, the sun is often in more abundant supply.

With a wood heater loop, lots of hot water is available four to eight months of the year (depending on climate), but the unwanted space heat in the warmer months can make the system unworkable for year-round water heating. In this situation, combining wood and sunshine (using a solar water heating system) for water heating can work very well—and propane can be the backup.

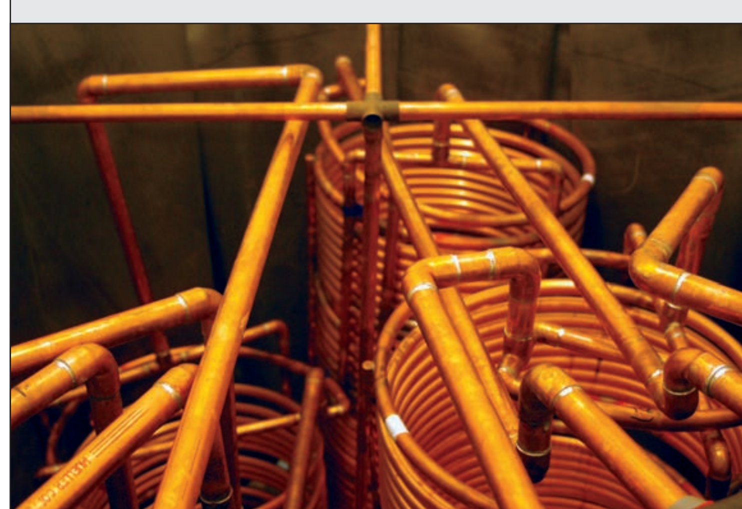
With an outside boiler, it's possible to make hot water year-round, but an SWH system can often provide a large amount of the hot water needed—without the work of harvesting firewood and keeping a fire going. If propane backup is used, it needs to be thermostatically controlled and, to avoid overheating, be able to remain off or be bypassed when wood or the SWH system is providing all of the heat.

The best method for integrating these two fuel sources depends on whether you are using a small wood heater or a large wood boiler. Wood boilers typically require a large-capacity buffer tank to achieve their highest efficiency. This buffer tank also provides an easy place to store solar-heated water. Since the buffer volume is large enough to handle the wood boiler, it is usually more than sufficient to serve all water-heating loads.

When the buffer tank is unpressurized, a heat exchanger can be added. But old propane tanks are sometimes used as buffer tanks. Since the water in these tanks is under pressure, integrating this with an SWH system requires attention to detail. An external heat exchanger, such as a flat-plate or a shell-and-tube type, is often used in these applications.

Integrating an SWH system with a wood heater is more complicated. Solutions include plumbing tanks in series with the solar-heated tank prefeeding the wood-heated tank, or using tanks that allow for multiple heat inputs, such as a dual-coil indirect tank. One option, shown in the photo below, is to have a single heat exchanger in the tank for a pumped source, and thermosiphon from the other source. In this example, the passive thermosiphon occurs from the wood heater using domestic water and the SWH system is closed-loop, glycol and pumped.

Right: Large, unpressurized tanks are an effective way to integrate a wood boiler with solar water heating. These tanks are highly adaptable, allowing heat exchangers to be used for delivering heat to the tank and for delivering it for domestic water and/or space heating.



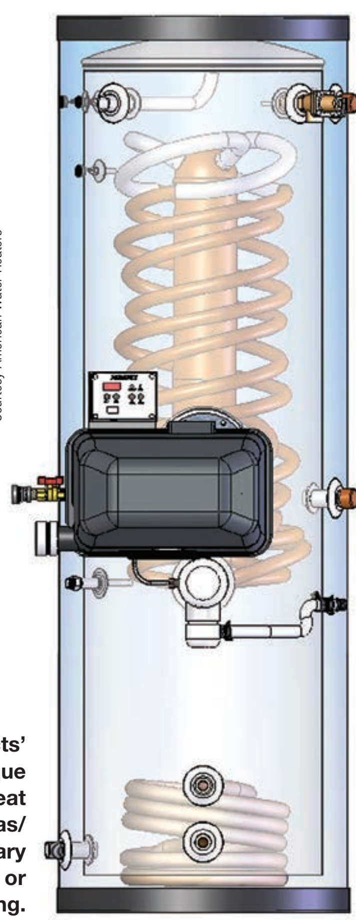
Vaughan Woodruff

Right: A Rinnai tankless gas water heater.

Courtesy Rinnai

Left: American Water Heaters' high-efficiency, tank-type gas water heater.

Courtesy American Water Heaters



Right: Heat Transfer Products' Phoenix Ultra is a unique combination of a solar heat exchanger with integrated gas/LP backup, and an auxiliary connection for air handlers or radiant heating.

Courtesy Heat Transfer Products

Propane

If you are looking for hot water fuss-free and whenever you open a fixture, you may find propane to be the most suitable solution, but it's nonrenewable and fraught with social and environmental implications. For locations accessible by a propane truck or to which propane bottles can be easily transported, propane provides an automated water heating option.

If space is a premium, a tankless propane water heater is the most suitable water heating solution. For off-grid applications, consider:

Condensing water heaters are the most efficient tankless type because they recapture energy from the water vapor in the flue gas. They can use PVC venting due to the lower flue gas temperatures and the less corrosive condensate that forms in the venting. In a non-condensing water heater, the water vapor escapes the venting at higher temperatures. Condensing water heaters are more expensive, but can increase efficiency by 15% over non-condensing models.

A **temperature-modulated** water heater measures the incoming water temperature and the flow, and adjusts the burner to achieve the desired output temperature. If the incoming water temperature is 45°F, it may provide its maximum flame to achieve 120°F. If the water feeding the water heater has been preheated to 100°F by a wood heater or SWH system, the flame is adjusted lower to still reach 120°F. Flow-modulated models respond to the flow rate, but not the incoming water temperature, and should not be used with preheated water.

Electrical requirements of propane water heaters for off-grid use are important to consider. Most conventional tankless water heaters use electronic controls and igniters. These units are designed to always have electricity, which may keep the inverter awake when it might otherwise be in sleep mode. (Other models use a piezo igniter or an igniter that is powered by the incoming water flow and do not require an electrical source.) One less apparent electrical consideration is the unit's minimum operating water pressure. For example, if the unit requires a minimum water pressure of 30 psi, it could significantly impact the well-pump requirements, or not work in low-pressure gravity-fed water systems.

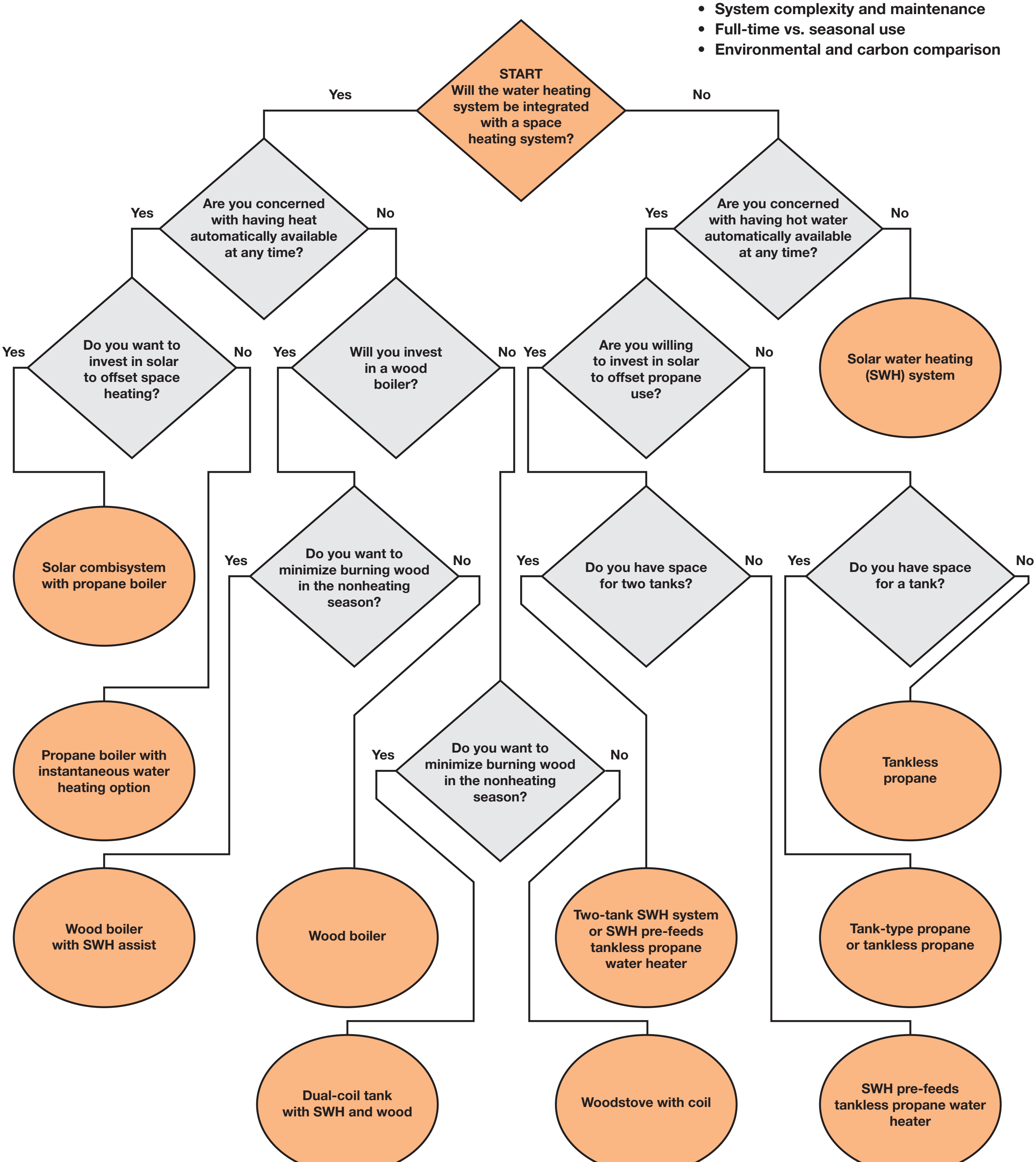
Many wall-hung propane boilers used to feed a hydronic space-heating system can utilize a relatively inexpensive upgrade to also provide instantaneous water heating. This approach can reduce equipment costs, but is often incompatible with supplementary water heating from solar or wood since the output for water heating is not temperature-modulated.

Many off-grid homes use a 40- or 50-gallon propane tank-style water heater due to the low equipment cost. Since the burners on these appliances are at the bottom of the tank, integrating the system with solar or wood typically requires careful consideration. In an effort to maintain the efficiency of heating water with RE, a second tank is usually incorporated. The water from this tank then enters the propane water heater. If the water heated by the SWH system or wood heater is above

Selecting Your Systems

The system you use to heat your domestic water off-grid will depend on your values and situation. Key factors may include:

- **Climate considerations**
- **Wood availability**
- **Available electricity for controls, etc.**
- **Cost comparison**
- **System complexity and maintenance**
- **Full-time vs. seasonal use**
- **Environmental and carbon comparison**



the propane heater's setpoint, however, the burner won't fire. Trying to integrate solar directly into a propane-fired tank would limit the contribution of the SWH system and lead to overheating issues.

If you use a propane boiler to provide space heating along with an SWH system, using an indirect water heater can streamline this integration. Almost every major water heater manufacturer offers dual-coil indirect water heaters with a heat exchanger in the lower portion of the tank for the SWH system and a heat exchanger in the upper half of the tank for a boiler. This allows the propane boiler to provide constant water temperatures and for the SWH system to preheat the incoming water.

Advanced indirect water heaters can simplify integrating an SWH system and a propane-fired boiler for domestic water heating and space heating. One style of these "combisystems" is a tank-in-tank design—a stainless steel domestic water tank immersed in a large buffer tank. The boiler and the SWH system heat the boiler water in the buffer tank, which in turn heats the domestic water in the stainless steel tank. Another design uses a large coiled heat exchanger instead of the boiler tank. The domestic water flows through the coil and is heated by the surrounding buffer water. This approach is preferable for solar combisystems in off-grid applications, as the other approach typically requires the use of additional electrical valves and pumps.

resources

"Solar Hot Water System Types & Applications" by Chuck Marken in *HP141* • **homepower.com/141.48**

"Site Assessment for Solar Water Heating Systems" by Vaughan Woodruff in *HP149* • **homepower.com/149.64**

"Solar Collectors—Behind the Glass" by Chuck Marken in *HP133* • **homepower.com/133.70**

"Solar Water Heating Basics" • **homepower.com/articles/solar-water-heating/basics/what-solar-water-heating**

"Efficient Water Heating Options" by Alex Wilson in *HP152* • **homepower.com/152.80**

Finalizing Your Plan

Ultimately, your water heating approach will be a balance between cost, convenience, and comfort. As you select the best fuel sources to fit your needs, it is best to err on the side of simplicity. The flow chart on page 55 provides some proven options to get your job done.

Comment & Discuss this article @ homepower.com/177.58

The 2017 *National Electrical Code*

by Brian Mehalic

It's that time again—a new edition of the *National Electrical Code (NEC)* has been published. Early-adoption states are already beginning to enforce it, and folks in the industry—ranging from installers to designers to manufacturers—are studying it. And in case you haven't noticed, a PV array made the cover—a clear indication of both the rapid growth in deployment of PV systems, as well as the significant changes in regard to PV systems that have occurred in the *NEC*.

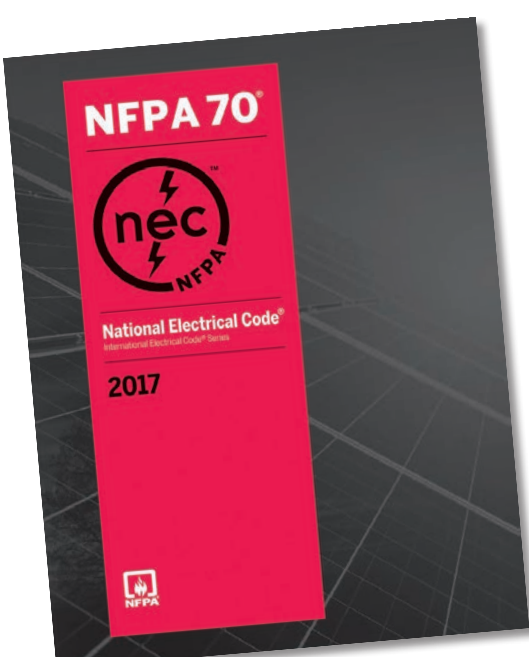
New Articles

Section 690.10 now refers to the new Article 710, "Stand-Alone Systems." While the majority of requirements in Article 710 are the same as they were in Section 690.10 in 2014, the article's scope applies to sources "operating in stand-alone mode," thus covering multimode systems (which can be both grid-tied and stand-alone, and to which Article 690 also applies). Load-side wiring of stand-alone systems is covered in 710 as well as many other articles in chapters 1 through 4 of the *NEC*. Since stand-alone systems may or may not incorporate a PV system, it made sense to move them from PV-specific Article 690.

New Article 691 applies to "Large-Scale Photovoltaic (PV) Electric Power Production" facilities—specifically those with a generating capacity of at least 5 megawatts AC. Generating capacity is a newly defined term—it is the sum of the rated continuous power output of all parallel-connected inverters at 40°C (104°F). The popularity of large-scale PV systems is rapidly growing. Since these systems are "operated for the sole purpose of providing electric supply to a system operated by a regulated utility" and only accessible by qualified personnel, large-scale PV systems now have exemptions from a few requirements in Article 690, as well as the opportunity for engineered designs that may result in methods and materials not permitted under other sections of the *NEC*.

The introduction of Article 706, "Energy Storage Systems (ESS)," reflects *NEC* efforts to keep up with industry developments. Article 706 focuses on systems—both AC and DC—including unconventional storage technologies (such as flow batteries, capacitors, and flywheels) and associated equipment. Three types of ESS are defined: "self-contained" (assembled, packaged, and installed in a single unit or container, and usually "manufactured by a single entity"); "pre-engineered of matched components" (field-installed, consisting of separate components supplied as a system); and "other." ESS of up to 100 V are allowed in dwelling units; if there are no live parts accessible during routine maintenance, the voltage can be higher (with no stated limit). Products already on the market that exceed 100 volts and that are intended for use in residential applications will fall under this allowance.

Also new in the 2017 *NEC* is Article 712, "Direct Current Microgrids."



Courtesy NFPA

New Illustrations

Figures provided in 690.1(a) and (b) have several modifications and new illustrations, including schematics showing differences between AC- and DC-coupled multimode systems. The most significant modification is the specification of the PV system disconnect location in each of the drawings—on the AC output side of interactive inverters, and between the PV power source and any other equipment in DC-coupled multimode and stand-alone systems. Along with changes in Article 690, Part III (Disconnecting Means), this should help provide clarity for what had previously been a difficult-to-decipher part of the *NEC*.

Rapid Shutdown—with Delay

Major changes and clarifications have been added to Section 690.12, "Rapid Shutdown of PV Systems on Buildings." First is the definition of an array boundary as being 1 foot (instead of 10 feet) from the array in all directions. Outside-of-the-array boundary requirements in Section 690.12(B)(1) for controlling conductors are similar to the 2014 *NEC*, but with new specifics regarding the initiation device in 690.12(C).

A new requirement (690.12(B)(2)) states that conductors inside the array boundary be limited to less than 80 V within 30 seconds of initiation of rapid shutdown; or be listed or field-labeled as a rapid shutdown PV array; or have no exposed wiring methods and be more than 8 feet from exposed grounded conductive parts and the earth. This will essentially necessitate module-level shutdown for systems on buildings; using module-level electronics like microinverters or DC-to-DC converters; or the use of products that are listed for providing rapid shutdown protection or are isolated from grounded surfaces and equipment.

This requirement does not become effective until January 1, 2019, which is especially important if you live in an early adopter state. This delay gives the industry—and particularly, manufacturers—time to develop and list new products and approaches to comply with this more stringent requirement.

Additionally, there are now many specific labeling requirements for systems equipped with rapid shutdown, detailed in 690.56(C), which also includes example drawings. Essentially, the two labels are to distinguish between pre-2019 installations that only control conductors outside the array boundary, and installations that comply with both 690.12(B)(1) and (2).

PV System Grounding

One of the most interesting changes in the 2017 *NEC* pertains to system grounding. Previously, the *NEC* treated PV systems as if they were solidly grounded. Modern PV systems do not have a main or system bonding jumper between a grounded conductor and the ground on the DC side. In "grounded" systems, this connection is typically through a fuse or breaker (a resistive device that serves as the ground-fault protection device); in "ungrounded" systems, there is no connection from either of the DC conductors to ground.

To help clarify, a new definition of "functional grounded PV system" states that the system "has an electrical reference to ground" but is "not solidly grounded." An informational note to Section 690.47(A) further elaborates on this.

The implications of this change in the PV system grounding terminology ripple throughout Article 690: 690.35 has been deleted, as ungrounded systems are now one of the six types of PV system grounding configurations allowed in Section 690.41(A). Section 690.5 has become 690.41(B), as ground-fault protection applies to practically all PV systems (except solidly grounded systems, which must be two or less PV source circuits and cannot be on or in buildings). Section 690.47 has been dramatically reduced in length, permitting the AC equipment-grounding conductor to be the connection to any ground-fault protection, and refers to Article 250, "Grounding and Bonding," for the means and methods of making these connections. Definitely a topic for a future in-depth "Code Corner."

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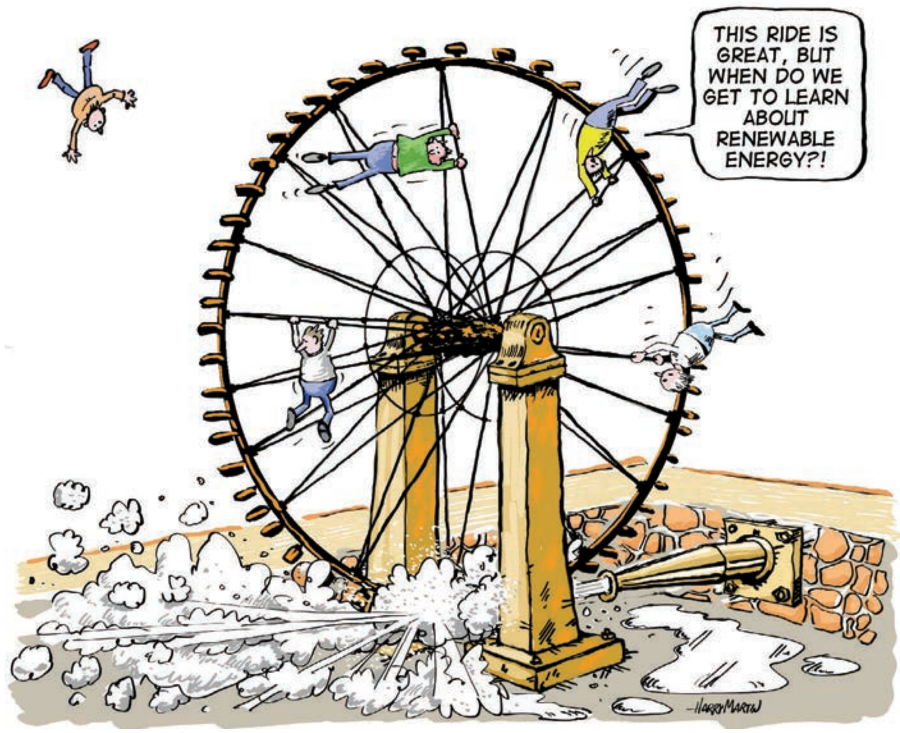
Solar Pioneers Party —Part Deux

by Kathleen Jarschke-Schultze

My husband Bob-O and I attended the second of a trilogy of celebrations honoring the pioneers that brought solar (and other renewable energy) into the lives and mainstream of America. Jeff Spies' dream of a Solar Pioneers Party (SPP) once again enriched and recorded the history of the movement that brought us to this place.

This year, SPP.2 was held in Grass Valley, California. The Nevada County Fairgrounds/RV park was very accommodating to our motley assembly of tents, travel trailers, teepees, and gypsy caravans. Pretty, spacious, and clean, the fairgrounds are open to the public during the day. I saw many young mothers with their small children—riding bikes, scooters, and skateboards along the paths—safe from traffic. What a terrific way to use the fairgrounds off-season.



Gold Mining Museum

The Northstar Mining Museum was only a couple of blocks away, housed in the original Northstar Mine Powerhouse. This museum is truly a gold mine of the history of the Pelton wheel.

The original powerhouse walls are 2 feet thick and made with native stone. The building and picnic areas sit next to a creek. But the first thing you see as you arrive are two enormous Pelton wheels.

This is an excellent museum with a gregarious and knowledgeable staff. It houses the powerhouse's original Pelton wheel next to the world's largest diameter (30-foot) Pelton wheel in its original race. Although Pelton claimed the wheel would be too large to operate properly, it did work quite well. The wheel was constructed in parts in San Francisco and assembled in the powerhouse.

The sheer number and quality of historic artifacts and power equipment from a bygone time was amazing. The yard surrounding the powerhouse has quite a display of mining tools and equipment—Little Giants (hydraulic mining nozzles), a small rail car used to haul miners down a deep, steep mine shaft; more Pelton wheels; and pieces of stamp mills. I had never seen a wooden gold-mining pan before, but here were two kinds—one Russian, a tray carved from a large piece of wood, and one shaped like the classic metal pan. (I think they would make great bread-rising bowls.) I was fascinated with the hydro-powered wringer washing machines. There was even a large wooden cash register with clay balls that dropped into grooved tracks like an abacus marble game. Have you ever seen a dynamite packing machine? Well, now I have.

Party President

Jeff Spies and his crew of volunteers and supporters pulled off another epic gathering. Sponsors were Backwoods Solar, Home Power, Inovateus Solar, PV-Cables, and SunJack. A special recognition goes to volunteers Katy Collardson, Sequoya Cross, Kelly Larson, Guy "Super Guy" Snow, Colleen Spies, Sam Vanderhoof, and Kristen Whitley. I know that many attendees also donated their time and effort when needed and made the event really wonderful. Even though there were organized events within the party, there was plenty of time to just talk with old friends.

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Kathleen and solar pioneer Chris Carter check out the world's largest Pelton wheel—30 feet in diameter. It produced 1,000 horsepower from 354 psi through a 1.75-inch nozzle. The penstock was 20 inches in diameter and 7,070 feet long. At its perimeter, the wheel moved 70 mph.

Dr. Solar

One of my favorite sights was a solar gypsy caravan paired with another caravan that opened into an old-time medicine show stage. We were treated to humorous performances by Dr. Solar, Steampunk Magician (aka Terry Robinson). Once an anti-nuclear street performer, he's now a traveling magician promoting green living and renewable energy.

Another of the popular activities was storytelling by the solar pioneers, who regaled folks with stories from the early days of renewable energy. I'm sure some of these stories were told for the first time there, interspersed with old favorites.

Panel of Plenty

One evening, after we had gathered for a great catered dinner, Jeff put together a panel of solar pioneers—John Berdner, Jonny Hill, Cully Judd, David Katz, Ron Kenedi, Mark Mrohs, Wayne Robertson, Rob Robinson, John Schaeffer, Sam Vanderhoof, Johnny Weiss, Elizabeth and Steve Willey, and Charlie Wilson.

There were many and varied stories told, but only Elizabeth and Steve Willey (who started Backwoods Solar) provided vivid details about their first installed PV system. They had loaded up the equipment and tools on a motorcycle and drove across the border into Washington from their Sandpoint, Idaho, home. They installed the small off-grid system, got back on their motorcycle, and headed home. They noticed a large, dark cloud behind them and sped up to get home faster. It was May 18, 1980, and the dark cloud they had seen was Mount St. Helens erupting. The next day, the ash started to fall. Steve had to climb on the roof to block their rain catchment system.

Solar Pioneer Documentary

Along with celebrations of the solar pioneers, Jeff Spies is working with Jason Vetterli to put together a documentary. Their project began with interviews of pioneers last year. Jeff and Jason have been traveling to many remote sites to gather the stories, histories, and opinions on the state of the industry. They spent a weekend with us at our homestead, and then traversed the road less traveled to interview Richard Perez (who, with his wife Karen, founded *Home Power*) at Agate Flat, Oregon. The documentary crew took advantage of the first SPP and this year's gathering with the assistance of Kristen Huster Young, who added to the wealth of video footage.

After a lovely group dinner on Friday, we were treated to a 17-minute video teaser produced by Jason. The final interviews are scheduled soon, and Jeff and Jason will take the next year to compile and edit the footage. They hope to debut the Solar Pioneer documentary at next year's third and final SPP.

We thoroughly enjoyed visiting with our old friends without having to rush back to a booth or leave to give a lecture, as happens at other renewable energy events. We visited and caught up with what these mostly retired friends are doing now. The old stories all seem so far away now and are veiled with the humor that time paints over formerly calamitous adventures.

Right: Dr. Solar (aka Terry Robinson). Below: The medicine-show caravan he uses to promote green living and renewable energy use.

Courtesy Kathleen Jarschke-Schultze (2)

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Hydro Power Calculations

Hydropower is a combination of vertical drop ("head") and flow. But how much power (W) and energy (kWh) can a particular hydro resource yield?

A basic formula, confirmed by experience, tells us that head (in feet) times flow (in gallons per minute; gpm) divided by a factor gives continuous power output (W). The factor can range from about 9 to 14, depending on the size and efficiency of the system, whether it's battery-based or not, and other parameters. For conservative convenience, let's use a factor of 12, which is perhaps best for a whole-house system estimate if we don't have more information. (In reality, each resource will need a different factor, and the comparisons here are for demonstration only.)

Head (ft.) × Flow (gpm) ÷ 12 = Power (W)

It's important to understand the relationship between watts and watt-hours. Watts are instantaneous power. Watt-hours are units of energy—what we use, generate, buy, and sell. Multiplying watts by length of time in hours gives us watt-hours. Dividing by 1,000 gives us kilowatt-hours (kWh). Since hydro systems usually run all the time, we can easily calculate daily energy generation—wattage times 24 hours.

Hydro turbine power × 24 ÷ 1,000 = kWh per day

Examples can help confirm the important hydro fact—it's all about the resource. How much energy you want, the rating of the turbine, and any other factors are unimportant in the basic calculation of your site's hydro potential!

Ian Woofenden

Low-Head Site

A site with only 3 feet of head will need a lot of flow to generate significant energy. This is why you see this sort of site with a dam and nearly all of the water going through the turbine.

3 ft. × 2,000 gpm ÷ 12 = 500 W
× 24 hrs./day = 12,000 Wh/day
÷ 1,000 = 12 kWh/day

Large High-Head Site

"High head" might be used to describe any site with more than 10 feet of head.

300 ft. × 400 gpm ÷ 12 = 10,000 W
× 24 hrs./day = 240,000 Wh/day
÷ 1,000 = 240 kWh/day

Home-Scale High-Head Site

While stream heads and flows vary dramatically, finding a site with a head ranging from 40 to a few hundred feet and a flow of 20 to 100 gpm is fairly common.

120 ft. × 45 gpm ÷ 12 = 450 W
× 24 hrs./day = 10,800 Wh
÷ 1,000 = 10.8 kWh/day

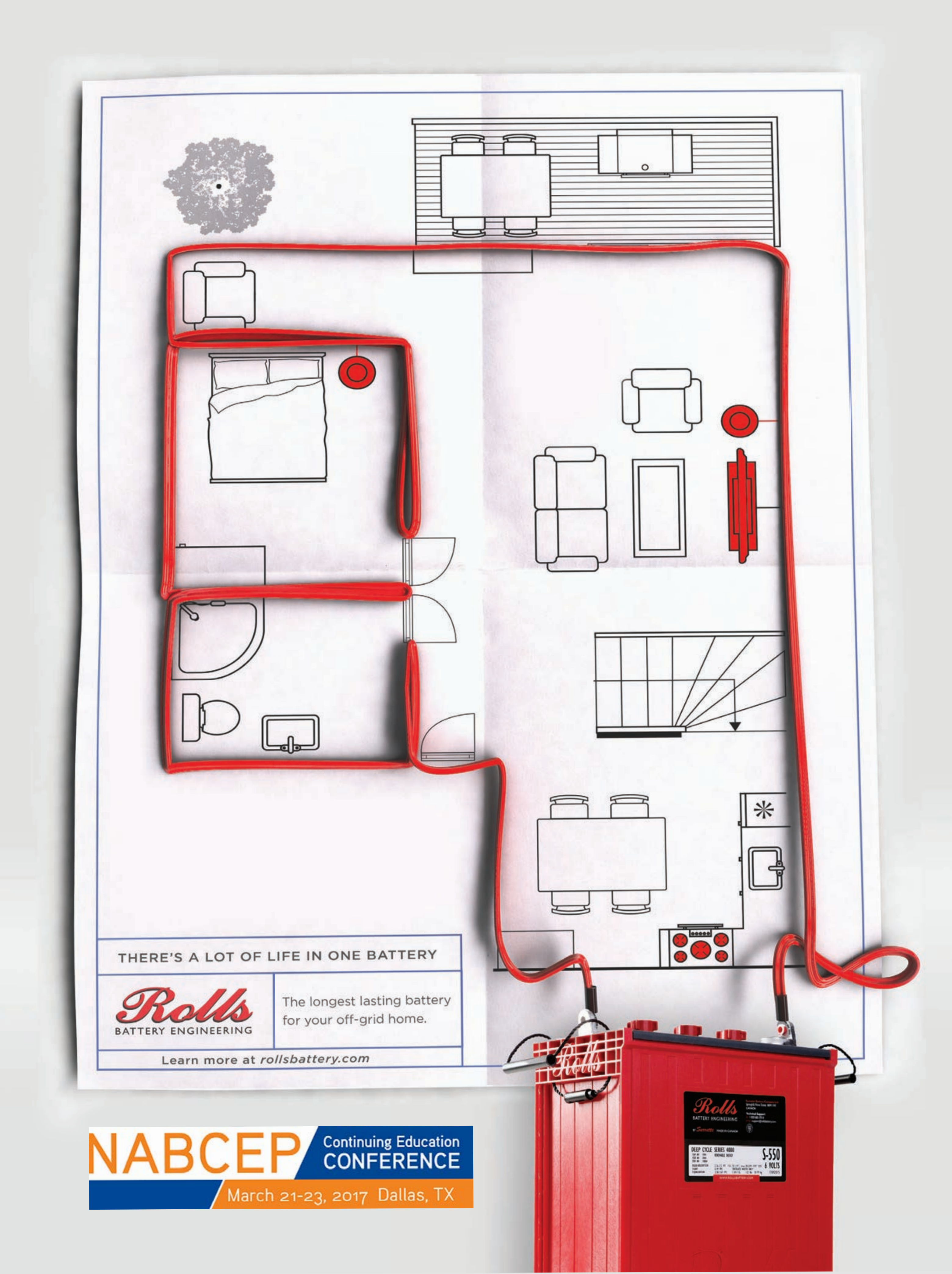
Industrial Downspout

Even a large building in a rainy environment does not present a realistic hydro "collector," so you can forget about your home's roof. A typical hydro system has a collector area measured in square miles. An 80,000-square-foot flat roof on a warehouse in Seattle (which receives 38 inches of rain per year) will yield an average downspout flow of 3.6 gpm. Even if that warehouse roof is 60 feet tall, the production numbers are not impressive:

60 ft. × 3.6 gpm ÷ 12 = 18 W
× 24 hrs./day = 432 Wh/day
÷ 1,000 = 0.432 kWh/day

Dreaming about hydropower is fun. Really making hydropower happen must start with real measurements of the head and flow, and calculations of the power and energy available.

—Ian Woofenden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