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Small is Beautiful


Courtesy EnergySage

& Appropriate is Best

Over the years, the words "small is beautiful" have appeared in *Home Power* many times—usually in reference to home size, but also applicable to renewable energy systems and as an overall approach to living as sustainably as possible. Not only is this phrase the title of an excellent book (the "study of economics as if people mattered" is the book's subtitle), but it is also a guiding force for those, like myself, who believe that *appropriate technology (AT)* must be chosen so that humans and other inhabitants can be sustained on our finite planet. AT is an ideological way of doing things, encompassing small-scale, energy-efficient, environmentally sound, and climate-specific, local solutions.

In the early days of *Home Power*, the magazine was a cutting-edge source of energy information for remote off-gridders. Folks began to grasp that fossil-fueled generators were not really an appropriate technology to provide electricity for their back-to-the-land lifestyle, and *Home Power's* renewable roots spread from there.

As solar electricity has moved into mainstream consciousness, many people not drawn to an alternative, off-grid lifestyle have become interested in renewable energy and energy-efficient building. Some pages of *Home Power* have reflected that diversity—you'll see "larger" homes and larger RE systems featured in the magazine.

There are many ways to evaluate the impact of green building and renewable energy systems—amount of carbon and fossil fuel offset, embodied energy, support of the local economy and local labor—and these are all considerations in evaluating what we present on our pages. We want to show you cutting-edge technologies that work—and keep encouraging the evolving conversation about what is appropriate.

But our readers occasionally point out that larger homes and their larger, more complex systems—even though they use energy-efficient and appropriate technologies—are still much less sustainable than choosing to scale back. Americans make up 5% of the world's population, yet consume 25% of the world's resources—and *Home Power* wants to help change that. A small, well-built, efficient home consumes less material in its construction (saving money and contributing less pollution) and, having fewer appliances and loads, requires less energy and materials to operate over its lifetime.

If you have or are building a small, efficient green home that fits the bill, we'd love to hear from you. Your home could be featured in *Home Power*. What do you say?

—Michael Welch, for the *Home Power* crew

Think About It...

Any intelligent fool can make things bigger and more complex...It takes a touch of genius—and a lot of courage—to move in the opposite direction.

—E.F. Schumacher

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may & june 2016

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On the Cover

Forrest Harcourt (right) and Dakota Jakiela (left), up-tower with an Endurance S343.

Photo courtesy Gary Harcourt

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Photos: Courtesy Chris Farmer; David Patterson; Green Hammer


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Photos: Courtesy Andrew Kurtz / APRS World; Brian Mehalic

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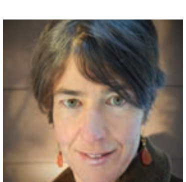
this issue's experts

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

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

At the age of 20, **Chris Farmer** realized that he'd never eaten anything homegrown—and set out to change that. At 22, he helped start Rising River Farm, an organic farm in Washington State. Since his move to Earthaven in North Carolina in 1998, Chris has helped grow organic vegetables, design and build passive solar homes, and design and install off-grid energy and water systems.

Author and educator **Dan Fink** has lived off the grid in the Northern Colorado mountains since 1991, 11 miles from the nearest power pole or phone line. He started installing off-grid systems in 1994, and is an IREC Certified Instructor for both PV and small wind. His company, Buckville Energy Consulting, is an accredited Continuing Education Provider for NABCEP, IREC, and ISPQ.

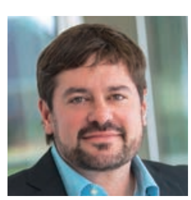


Environmental writer **Juliet Grable** lives in southern Oregon, where she writes about sustainable building, renewable energy, and issues related to water conservation and watershed restoration. This year, she completed training to serve as an Ambassador Presenter for the Living Building Challenge.

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.

Chuck Marken is a *Home Power* contributing editor, licensed electrician, plumber/gas fitter, and HVAC contractor who has been installing, repairing, and servicing SWH and pool systems since 1979. He has taught SWH classes and workshops throughout the United States for Sandia National Laboratories, Solar Energy International, and for many other schools and nonprofit organizations.

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.



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.

Kent Osterberg worked as an electrical engineer in the electric utility industry prior to moving to Oregon in 1989. In 1991, he installed one of the first grid-connected systems in Oregon at his residence. Kent is the principal system designer and installer for Blue Mountain Solar in Cove, Oregon.

Jim Riggins is a retired energy rater, building analyst, Energy Star partner, and EPA WaterSense inspector. He volunteers with the Colorado Renewable Energy Society and Habitat for Humanity. He and his family live in a net-zero energy passive solar home he designed, featured in *HP141* and *HP150*.

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

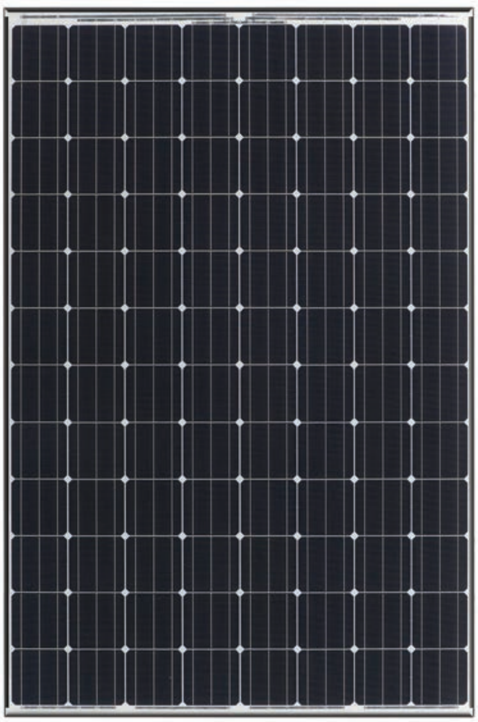
Allan Sindelar installed his first off-grid PV system in 1988. He retired from Positive Energy Solar of Santa Fe, New Mexico, in 2014, and now designs, services, and consults on off-grid and water pumping systems. He is a licensed electrician with dual NABCEP certifications.

Michael Welch, a *Home Power* senior editor, is a renewable energy devotee who celebrated his 25th year of involvement with the magazine in 2015. He lives in an off-grid home in a redwood forest in Humboldt County, California, and works out of the solar-powered offices of Redwood Alliance in nearby Arcata. Since 1978, Michael has been a safe-energy, antinuclear activist, working on the permanent shutdown and decommissioning of the Humboldt Bay nuclear power plant.

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

Contact Our Contributors

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



Courtesy Panasonic

Panasonic N325/ N330 HIT

PV Modules

Panasonic (bit.ly/HITsolar) has announced large-capacity high-efficiency HIT modules, in 96-cell 325- and 330-watt models. At 19.7% efficiency, these modules have a hetero-junction cell structure—monocrystalline cells surrounded by a thin layer of amorphous silicon. They have a positive-only power production tolerance (+10%/0%), a 15-year materials warranty, and a 25-year power warranty. Electrical specifications: N325: 57.6 Vmp, 69.6 Voc, 5.65 Imp, 6.03 Isc; N330: 58.0 Vmp, 69.7 Voc, 5.7 Imp, 6.07 Isc.

Iron Edison

Lithium-Iron Batteries

Iron Edison (ironedison.com), of Lakewood, Colorado, offers lithium-iron phosphate (LiFePO4) batteries in 12, 24, and 48 V configurations, making them compatible with standard battery-based inverters. Storage capacity ranges from 180 to 1,000 Ah. Pre-assembled with a battery management system and DC disconnect, they're housed in a steel enclosure with a removable lid. These maintenance-free batteries are rated for 5,000 cycles (about 14 years) at 50% depth of discharge, and have a standard seven-year prorated warranty. Lithium-iron phosphate batteries are touted for their safety and stability, as they are not prone to thermal runaway that has been problematic for other lithium battery technologies.

—Justine Sanchez

Courtesy Iron Edison

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2016 Renewable Energy Fairs

Energy fairs are a great way to introduce yourself and your family to homemade renewable energy. They almost always include the technologies that surround RE, such as alternative transportation and electric vehicles, green building, and energy efficiency for homes and businesses.

While there are fewer of them each year—mostly due to the burgeoning amount of information that is available on the Internet—don't miss out on these opportunities to attend workshops, hobnob with experts, see the latest technologies, listen to solar-powered music, and to socialize with some like-minded folks.

Northwest & Alaska

Jul. 23
NW SolarFest • Shoreline, WA • nwsolarfest.org

Aug. 14
Chena Hot Springs Renewable Energy Fair • Chena, AK • chenahotsprings.com

Midwest

Jun. 17 – 19
The Energy Fair (aka MREF) • Custer, WI • midwestrenew.org

Jun. 24 – 25
Michigan Energy Fair • Mason, MI • glrea.org

Aug. 20 – 21
Illinois RE & Sustainable Lifestyle Fair • Oregon, IL • illinoisrenew.org

Sep. 17
Clean Energy Fair • Helena, MT • montanarenewables.org

Northeast

Jul. 15 – 16
SolarFest Sunrise Festival • Manchester, VT • solarfest.org

Southwest

Aug. 12 – 14
Crestone Energy Fair • Crestone, CO • scseed.org

If you know of an energy fair that we've missed, please send contact info to hp@homepower.com for next year's announcements.

NW SolarFest

Courtesy Ben LaCourse (2)

Clean Energy Fair

Courtesy Ben Reed (2)

For the Pros

Jun. 13 – 15
Small Wind Conference • Stevens Point, WI • smallwindconference.com

Jul. 11 – 14
Solar 2016 (ASES) + Intersolar North America • San Francisco, CA • ases.org

Sep. 12 – 15
Solar Power International • Las Vegas, NV • solarpowerinternational.com


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Selecting Appropriate PV Array String Sizes

To appropriately size a PV array to an inverter, it is necessary to make sure that the:

- PV array never generates more voltage than the inverter's maximum allowed input voltage
- Voltage remains within the inverter's maximum power-point tracking range
- Current is within the inverter's maximum current and short-circuit current specifications
- Power rating is appropriate for the inverter.

Equipment Specifications

Module specs can be found on the manufacturer's data sheet or on the back of the module. The values shown in the table are for a 54-cell module. The manufacturer includes a temperature coefficient for the peak power voltage. If the temperature coefficient for peak power voltage is not published, then the temperature coefficient for peak power, in percent, may be used as an approximation. Similarly, inverter specs may be found on the inverter data sheet or its label.

Example PV Module Specifications

Value	Rating	Temperature Coefficient, TC	
Power	190 W	-0.49% per °C	-0.931 W per °C
Voc	32.8 V	-0.34% per °C	-0.112 V per °C
Vmp	26.7 V	-0.47% per °C	-0.125 V per °C
Imp	7.12 A	-0.02% per °C	-0.0014 A per °C
Isc	8.05 A	+0.06% per °C	+0.0048 A per °C

Example Inverter Input Specifications

Item	Spec.
Rated power (W)	4,000
Input voltage (V)	200 - 600
Peak power tracking (V)	250 - 480
Minimum start voltage	285
Maximum input current (A)	18
Maximum short-circuit current (A)	25

Example Local Temperature Data

Data	Amount	Source
Record minimum	-28°C	weather.com
Extreme minimum	-17°C	solarabcs.org
High temp., 2%	32°C	solarabcs.org
High temp., 0.4%	37°C	solarabcs.org
Record maximum	42°C	weather.com

Editors' Note: Commonly, PV system designers use the ASHRAE "extreme minimum" temperature in calculating the maximum number of modules in series. The reasoning is that a module's voltage shouldn't reach its maximum until irradiance levels exceed 200 W/m^2, which will be after the record minimum temperature has occurred.

Temperature Data

Because a PV module's output depends on its temperature, calculations also must account for the lowest and highest possible site temperatures. One source for record temperatures is weather.com; another is SolarABCs.org, which has an interactive ASHRAE data map. A table of ASHRAE temperature data can also be found in "Expedited Permit Process for PV Systems" at SolarABCs.

For the first computation, which low temperature should you use—the ASHRAE tables' "extreme minimum" or the record minimum from the local weather station? The "extreme minimum" is a little misleading—half of all years will have at least one day that is colder than this temperature. The "extreme minimum" is actually the *average annual* minimum temperature. Since inverters should never see a voltage that exceeds the maximum input voltage, I choose to use the more conservative method—the record low temperature. If you use the "extreme minimum" temperature, you may get one extra module in the string, but on some cold winter day, that extra module may result in damage to the inverter or void its warranty.

continued on page 18

web extras

"Expedited Permit Process for PV Systems, Revision 2" by Bill Brooks, published by Solar America Board for Codes and Standards, July 2012 • **solarabcs.org**

"Outdoor PV Module Degradation of Current-Voltage Parameters" by Ryan M. Smith, Dirk C. Jordan, and Sarah R. Kurtz, NREL/CP-5200-53713, April 2012 • **bit.ly/NREL_PVdegrade**

continued from page 16

Calculate the Maximum Number of Modules in Series

The equation to solve for the maximum number of modules in series is:

$$\text{Max. series modules} = \frac{\text{Max input voltage}}{V_{oc} \times (1 + (TC_{Voc} \times (T_{Min} - 25)))}$$

Using example data from the table:

$$\frac{600}{32.8 \times (1 + (-0.0034 \times (-28 - 25)))} = 15.5$$

Since we have to work with whole modules, 15 modules is the maximum that can be wired in series.

Calculate the Minimum Number of Modules in Series

There are two factors to consider—PV module output degradation over time, and the effects of high temperature. Most studies of PV module degradation focus on power, concluding a median value for module power degradation of about 0.5% per year. Recently, the National Renewable Energy Laboratory (NREL) studied 12 mono- and poly-crystalline PV modules to see how the current and voltage parameters change over time. Relative to determining inverter string size, the significant finding was that 10 out of 12 modules showed less than 0.2% per year degradation in Vmp, with Voc remaining essentially unchanged. Since we're estimating a PV module lifespan of more than 25 years, we need to consider that Vmp may drop by 5% over the system's life: 0.2% per year × 25 years = 5%.

For the temperature factor, the ASHRAE "annual design dry-bulb high temp" value (either 2% or 0.4%), or the record high temperature may be used. The 2% temperature factor means only exceeding 2% of the time in the months of June, July, and August. The 0.4% temperature factor is only exceeded 0.4% of the hours during the hottest month—but there may be other months that it is exceeded. The temperature selected will determine how many hours every year the inverter may deviate from the maximum power point voltage.

Using the 2% temperature value will result in about 42 hours over the summer when the inverter may operate off its peak power point. With the 0.4% temperature, the inverter may operate off the peak power point for three hours during the hottest month of the year, and probably a similar number of hours for the other two summer months. If the record high temperature is used, the inverter should always be able to track the maximum power point. Since a small energy loss is far less critical than an inverter failure, there is no need to be conservative about which one is used. The sample documents provided in "Expedited Permit Process for PV Systems" use the 2% value. In my Oregon location, to be eligible for incentive money, I'm required to use the more conservative 0.4% temperature, which is used in the following calculation:

$$\text{Min. series modules} = \frac{\text{Min MPPT voltage}}{95\% \times V_{mp} \times (1 + (TC_{mp} \times (T_{Max} + T_{Add} - 25)))}$$

The minimum number of modules in series is 13 modules:

$$\frac{250}{0.95 \times 26.7 \times (1 + (-0.0047 \times (37 + 35 - 25)))} = 12.6$$

Since these modules are sitting in the sun and heating up during the day, the PV cell temperature will be hotter than the ambient air temperature and thus a temperature "adder" is used to estimate the PV module's cell temperature. Different temperature adders are used depending on the array mounting method (see table). This example assumes a roof-mounted array, for a temperature adder of 35°C.

Adder for Estimating Cell Temperature

Type of Mount	Adder
Pole or ground	25°C
Tilted rack on roof	30°C
Roof mount	35°C

Find the Maximum Number of Module Strings

The maximum number of module strings in parallel is the smaller of:

Inverter max Isc ÷ Module Isc, or
Inverter max Input ÷ Module Imp
= Max. series strings

25 ÷ 8.05 or 18 ÷ 7.12 = lesser of 3.1 or 2.5; = 2 strings

No temperature corrections are used because they are extremely small for current and because the inverter will simply clip power (rather than sustain damage) if current is higher than it is rated for.

Sizing the Array

Since PV modules generally operate at lower output compared to their standard test conditions (STC) rating, inverter manufacturers commonly specify a maximum array size up to 125% of the inverter output rating. Given a 4,000 W inverter, up to 5,000 W of PV modules (4,000 × 1.25) could be installed. In this example, the maximum number of modules would be 5,000 W ÷ 190 W per module = 26.3, i.e., 26 modules.

The possible combinations that may be considered for this inverter are: one string of 13, 14, or 15 PV modules or two strings of 13 PV modules. If we go with two strings of 13, we have a final array size of 4,940 W. Note, since one string would be at most 2,850 watts, it would be appropriate to select a smaller inverter for a single string of modules. But keep in mind the calculations will have to be repeated for the smaller inverter.

—Kent Osterberg

Heat-Pump Water Heater

Here's an update on the GeoSpring heat-pump water heater that we installed in our off-grid cabin in the Ouachita Mountains in July 2013. It continues to provide plenty of hot water in the heat-pump-only mode—I don't think that it has ever operated in resistance mode. If it has, the Trace SW4024 with a 240 V Trace transformer has handled the load.

In a very helpful June 2015 email response, Ian Woofenden suggested that I add more PV modules to my array instead of increasing the size of the battery bank. He noted that the more PV that I add, the less I'll need to rely on a generator.

I took his advice and enlarged the array. In the past year, we have expanded the battery bank and added 2,565 watts of PV for a total of 3,725 W.

I'm still reluctant to add a generator because it is at odds with our original intention of creating our own electrical energy—but I may ultimately have to do so. We may have hit the "sweet spot" of having the appropriate-sized array and battery for our consumption. So far, we still have power, and the battery bank recharges quickly when there is sun. Thanks for the help!

Joe Corcoran • Mena, Arkansas

Courtesy General Electric

Sustainable?

I am struggling to put into words my feelings after reading the article "Maximizing the Sun" in *HP171.* You left out a lot of details like square footage, number of occupants, and the embodied energy of the building materials used. I guess my main thought is that the house is not an example of a sustainable building. I thought sustainability was a cornerstone of what you stood for. If someone uses an enormous amount of money, an enormous amount of energy, and an enormous amount of building materials (along with their embodied energy) to build and operate a net-zero energy house, have they really accomplished anything?

Over the years, you have featured a few examples of sustainable homes, but most are top-end, energy-wasting behemoths. It leaves the impression that alternative energy housing is not for everyone.

My criticism is only to further the goal of sustainability, because if it is not sustainable, nothing else matters.

Ken Last • via homepower.com

Thank you for your comments on "Maximizing the Sun." This article was an excerpt from a book about the Desert Rain project, which was built to the standards of the Living Building Challenge (LBC)—arguably the most rigorous green building standard in existence. V2.1 of this comprehensive standard includes 20 imperatives in seven categories, or "petals:" site, energy, water, materials, health, equity, and beauty.

The chapter excerpted for Home Power *focused on energy, but Desert Rain is far more than "just" a net-zero energy house. It is also net-zero water—all project water is either harvested rainwater or recycled graywater, and all wastewater is treated on-site in a constructed wetland.*

The Materials Petal required that materials be sourced locally, whenever possible, and Desert Rain includes many thoughtful material choices that supported local craftspeople and manufacturers. No product or material used in the project could contain any chemical found on the Red List of the 14 "worst-in-class" chemicals and compounds that compromise human and environmental health. All wood used in the project is either FSC-certified or was salvaged from the site or from nearby sources.

I agree that we should have provided some "stats" for Desert Rain, which is actually a residential compound consisting of three units (maximum occupancy of 8): the main residence (2,236 square feet), Desert Sol, (489 square feet); and Desert Lookout, (815 square feet).

It is true that Desert Rain was an expensive project that exceeded its budget. But the homeowners were committed to the principles embodied in the LBC, and to the notion of Desert Rain as a demonstration project that would not only break trail for other LBC projects, but that would serve as a teaching tool for the hundreds of people for whom they open their doors. A good portion of the budget went to "soft costs"—vetting materials, engineering for unconventional systems, communicating with regulatory agencies, and the extra time associated with an integrated design process.

Juliet Grable

Electric Vehicle Winter Bonus

A 250-watt PV module can produce 1,200 to 1,500 EV driving miles per year. Our 9.4 kW PV array at Solar Acres Farm is generating more than 50,000 EV miles per year. Most people do not drive that much. The majority of the electricity on the farm is consumed in the household; some is used for chicken coop heating; and the rest is used for EV driving.

An EV has winter benefits as well. Since we have no garage, the EV is parked outside. Every night, it is plugged in to charge. The heating timer is set to come on 30 minutes before departure each morning. It preheats the car—the steering wheel, seat, and the cabin—and the car is totally de-iced. In addition, it is fully charged.

How many times have you been freezing going to a gas station in the morning? No longer with an EV! Our gasoline car is iced over in the morning, but the EV is ready to go. The preheat feature was a major factor in my decision to go electric, and a real bonus.

Jorgen Rasmussen • Solar Acres Farm,
Otis Orchards-East Farms, Washington

write to:

mailbox@homepower.com

or Mailbox, c/o Home Power
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Which Solar Application?

I've moved into a 1960s house in northwest New Jersey that has a modern, efficient oil heater for water and space-heating (using radiators). It has six rooms downstairs and two upstairs. There is also an unheated "three-season room" downstairs that I would like to convert into an office. And there is an existing swimming pool with no heater. We use well water.

I understand I can't replace the oil heat entirely with solar. So I'm wondering what the best energy-efficiency improvement is? Should I supplement water heating with a solar water heating system? Should I just set up a PV-powered radiant heating system for the three-season room? Should I just solar-heat the pool, which seems the most efficient use of solar energy? Or should I forget heating and use PV electricity to reduce my dependence on the local utility? Payback time is a consideration. (Note: There is also a propane-fired whole-house generator in place.)

Bob Doyle • Ringwood, New Jersey

It is difficult to give advice on what is optimal economically since it is so dependent on local incentives. Here are some guidelines that may assist your decision-making.

- Solar pool heating systems don't require incentives to have a good return on investment (ROI). The systems are so inexpensive that they are the No.1 solar heating system installed in the United States. They require about half the pool surface of pool collectors, so available roof space can be a factor.

- Grid-tied PV systems have dropped in cost dramatically and are eligible for the 30% federal tax credit, and with net metering potentially offer a good return on investment. Net metering allows building up a credit for any excess PV generation, which can be used during times of less production. Local incentives and net-metering rules for each state can be researched at dsireusa.org.

- A solar heating system to address either domestic hot water or space heating is probably the least cost-effective system to deploy if your oil burner is truly a high-efficiency appliance and the cost of oil remains at the present level for the next few years. Rising oil prices could change this. But it is difficult to have a good ROI with a solar water heater displacing the energy of a high-efficiency appliance burning a low-cost fuel.

- Environmental aspects should also be given careful thought in the solar installation decision-making process.

Chuck Marken • *Home Power* Thermal Editor

The roof space required for solar pool collectors is equal to about half of the pool's surface area.

Courtesy Engineered Solar

Generator for Well Pump

I am confused about what size and what kind of generator will run a 2 hp, 240 VAC, 30 A well pump. I know that the pump is using two-phase from the house. Although most generators state 240 VAC, they are only supplying one phase, so how can they run a two-phase pump? Are there any generators that can?

Stephen Maresch • via homepower.com

Well pumps are one of the most problematic loads. They can cause difficulties with systems powered by the utility grid, generators, and battery-based inverters.

One horsepower equals 746 watts. Theoretically, your 2 hp well pump should need only 1,492 watts to function. Unfortunately, the pump can draw a surge of three to four times its rated operating current just to start the pump, and your generator needs to be large enough to handle that.

Many modern well pumps include "soft-start" control circuitry to reduce the surge. But because removal and replacement can be expensive, people tackle pump-startup problems from the surface with a larger generator or retrofitted soft-start pump electronics.

The real-world power output of a generator can be drastically less than its rating. And plan on losing about 3% for every 1,000 feet above sea level, another 2% for each 10°F above the generator's rated temperature (usually 68°F), and yet another 10% if the generator is fueled by propane, rather than gasoline or diesel. A 10 kW propane generator operating at 8,000 feet elevation on a 90°F day may only produce 6,566 W.

Because you already have a 240 VAC split-phase pump and a 240 VAC split-phase generator, both legs of the alternator will be equally loaded. The load-balancing problem you refer to happens only when running a 120 VAC load from a 240 VAC split-phase generator—only one leg of the alternator is working to power each of its 120 VAC outlets, so the available generator output on each outlet is only half of the generator rating. Many modern generators have a switch that solves this problem by keeping both sides active. If there is no switch, you can add an autotransformer; these transformers can also be connected in reverse to power a 240 VAC split-phase pump from a 120 VAC source.

When sizing a generator for a well pump, first look up the pump make and model, and then consult the owner's manual or call the manufacturer for their generator size recommendations. Then, calculate and apply all of the environmental derating factors. And finally, add a bit of extra capacity—just in case.

Dan Fink • Buckville Energy

Permeability

I'm a bit confused by statements in the "Ask the Experts" piece in *HP171* regarding wall permeability and breathability.

One statement says "...moisture in vapor form is able to transpire from one side of the wall assembly to the other. This is a highly desirable trait, as it helps prevent excessive moisture buildup in the home and in the walls, and allows for dynamic drying of the wall to take place year-round."

I'm a retired general contractor, and all my research contradicts this. In addition to research, both building codes and requirements for the "Super Good Cents" homes I built back in the day require vapor barriers on the inside of walls and ceilings. (Ceilings are not required to have vapor barriers if the attic is adequately ventilated.)

The reason given is because, in cold weather without these vapor barriers, warm, humid air inside the house (in winter) will often reach dew point somewhere within the wall cavity, leading to condensation, wetness, mildew, dry rot, and reduced R-value in insulation. My building/designing career was in southwest Oregon. Are there other areas that can safely do without vapor barriers?

Malcolm Drake • Grants Pass, Oregon

This question comes up a lot when I am discussing vapor-open wall systems, especially with code officials and builders. The inclusion of a vapor "barrier" (an unfortunate term; I prefer "vapor control layer") is one strategy that can prevent moisture damage in a wall system, and it is intended to prevent moisture from condensing at a dew point within the wall when the wall materials (especially the insulation and the exterior sheathing) have no storage capacity and/or limited permeability. If water is "pouring" into a wall assembly faster than it can escape, this will lead to moisture damage, mold, and rot issues. Mineral-based insulation materials like fiberglass and rock wool have no ability to absorb humidity, and sheathing materials like plywood and OSB have a very limited ability to let humidity through, and hence the solution of trying to keep that moisture out of the assembly by using a plastic liner on the inside face of the wall to prevent it from getting in there.

The natural wall insulation materials we use in vapor-open wall systems have a vast storage capacity. These natural fibers absorb high levels of humidity in damp conditions and release that moisture in dry conditions. They can cycle through endless repetitions of this moisture loading, as long as they return to a reasonably dry state. A straw bale wall, for example, can safely store more than 1 pound of water vapor per square foot of wall area. That is vastly more than will make its way into the wall from diffusion and even from direct air leakage over a typical (Ontario, Canada) heating season. As long as the plaster on both sides of the wall has a reasonable perm rating (I recommend nothing lower than 4 U.S. perms), a natural-fiber wall insulation has no problem handling the moisture load it will experience as that moisture makes its way through the wall to the outside (or inside) atmosphere.

This strategy—combining permeable sheathing materials with natural fiber insulation and no vapor barriers—will work in virtually all climate zones. But it can't be done partway; the wall assembly must either be fully vapor-open, or it should follow conventions if conventional materials are being used. The worst scenario would be some mix of the two; that's a sure-fire moisture problem. But building with a completely vapor-open strategy using the right materials has been successful for many builders in many climates—some of us even hit Passive House levels of air tightness without using plastic barriers! And an increasing number of building scientists are starting to realize that this strategy has merit, and can actually result in a simpler and more resilient wall system.

Chris Magwood • Endeavour Centre

I state something similar in my original answer. "There is no need for a vapor barrier because the clay in the wall has a very high capacity to take on vapor when conditions are humid, to store it without any damage to the wall system and then to re-release it when the indoor or outdoor climate has changed. It is this ability that has enabled the historic buildings made of clay and fiber to endure for hundreds of years all over Europe and Asia."

I would add that the vapor barrier requirement is a fairly new one in the history of building, and now appears to be on its way out, refuted by most building scientists for all but the very coldest climates. If air cooling is used in the hot summer months, which is often the case even in a cold climate, then the vapor barrier can cause problems because the moisture drive—now from outside—can condense on the backside of that barrier. In-wall condensation issues have developed repeatedly in light-frame construction, which is most often insulated with materials that are negatively impacted in the presence of moisture.

Air-driven and diffusion-driven moisture is not an issue with mass walls with high clay content. The vapor is never driven far enough into the wall to reach dew point because the clay absorbs the moisture and because solid mass walls do not have the same kind of air-driven moisture issues as hollow-wall systems. How do we know? There are many hundreds of thousands of clay-based mass wall buildings all throughout Europe and Asia that have stood in cold and wet climates for hundreds of years without deterioration.

Paula Baker-Laporte • Econest Architecture

Earth Tube Follow-Up

I read Jim Riggins' "Mailbox" response on earth tubes in *HP159,* and would like some follow-up information. I live in Spanish Fork, Utah, and am building a geothermal greenhouse. I'm considering using earth tubes to bring in slightly earth-tempered air. What size and type of pipe did Jim use, and how deeply are they buried? My application won't allow me to go deeper than 4 or 5 feet, so I'm wondering if it will provide any benefit at all.

Darren Brown • Spanish Fork, Utah

continued on page 26

continued from page 24

I used ECOAIR 8-inch PVC pipe with antimicrobial coating (see amvicsystem.com). I installed it 10 feet deep. I am in Climate Zone 5, as is the Provo area, and roughly at the same latitude. In this climate zone, the soil reaches a year-round constant temperature at about 8 feet in depth. I added 2 feet to be conservative. The tube is 100 feet long.

I expect that these numbers are about the same for your area. You can contact a local university or do some research to confirm. At 5 feet of depth, you would certainly see some beneficial heating, but not as great as you would at 8 feet. The key would be to make sure you are below the frost line. One way to research this is to find out from your local building department the depth they require foundation stem walls to be built. If you cannot get below the frost line because of rocks or boulders, it is probably not worth installing the tube.

The antimicrobial-coated product is very expensive. Since you are heating a non-living space, you could consider uncoated, conventional PVC (white) or ABS (black) 8-inch pipe.

Jim Riggins • EnerSmart Energy Solutions

write to:

asktheexperts@homepower.com

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Power Sharing

Establishing an Off-Grid Community Microgrid

Story & photos by Chris Farmer

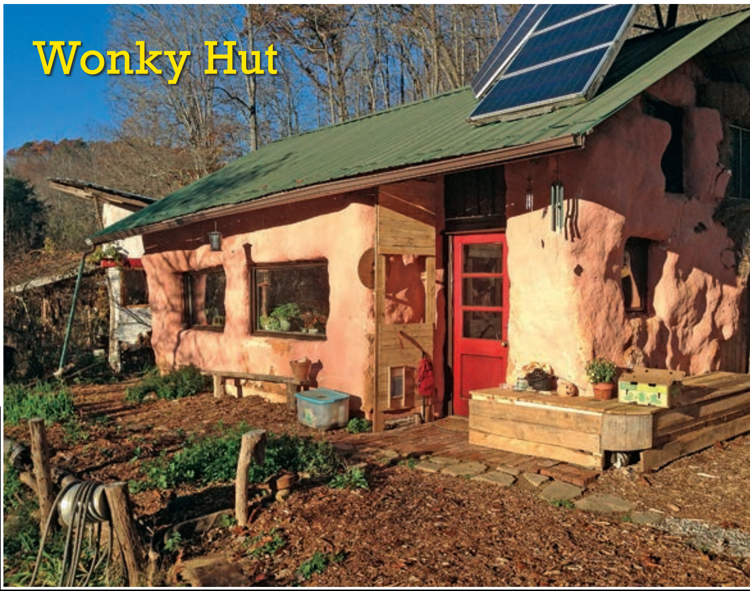
In June 2015, 22 residents of the Hut Hamlet neighborhood commissioned an 8.16 kW off-grid microgrid PV system at Earthaven Ecovillage, an intentional community outside of Black Mountain, North Carolina. The shared solar-electric system serves 10 small cabins, and the neighborhood kitchen and bathhouse. On an average sunny day, the system produces 31.5 kWh of electricity—what the average American house consumes—which is shared among the neighborhood homes.

Top: Brandon Greenstein and Chris Farmer, designers of the community PV system and custom weighted-metering system that helps in billing residents proportionally to their energy use.

Earthaven is a 21-year-old intentional community situated on 329 acres near the edge of the Blue Ridge Mountains. Presently, about 80 people live in the community year-round. Earthaven's mission is to create a village that is a living laboratory and educational seed bank for bioregionally appropriate cultures.

The entire community is off-grid, producing its electricity from several PV arrays (and two small microhydro turbines). However, after solar electricians Chris Farmer and Brandon Greenstein got repeated calls from the Hut Hamlet neighborhood residents asking them to troubleshoot, fix, or upgrade their old, owner-installed off-grid PV systems, Chris and Brandon proposed an upgrade—one state-of-the-art, code-compliant system to distribute conventional 120/240 VAC power to the entire neighborhood. While this idea technically made the most sense, the notion of sharing an off-grid power system brought up many issues:

- How to organize a group of neighbors to make decisions about creating an off-grid power system and deal with its many complexities
- What kind of entity needed to legally own the system, how to track everyone's different equity in the system, and how to leverage renewable energy tax credits
- How to equitably deal with the power system being shared among different people with different electrical loads, and different levels of consciousness about usage
- How to maintain a system with multiple owners



A few of the 10 residences powered by a central 8.16 kW off-grid photovoltaic system.

Sizing the Single System

Chris worked with the neighborhood's residents on an electrical loads spreadsheet to assess all of their existing and potential future desires for electrical loads, as some knew that they would likely want to install a refrigerator in their cabin in the next couple of years.

The great majority of loads on this system are lights; refrigerators and freezers; small plug-in loads (computers, modems, printers, chargers, and occasional small appliances, such as blenders and food processors); stereos; and a few small pumps (pressure and circulating). There are occasional larger loads of juicers, electric tea kettles and cooking plates, irons, and corded 15 A, 120 V power tools. The single largest load is the electric water heater used as a diversion load. This load is in the same building and very close to the inverter and AC distribution panel, and runs at a more efficient 240 volts (since it uses diverted excess energy, it is not included in calculations used for system sizing).

Hut Hamlet Estimated Household Loads

AC Loads	Qty.	×	Watts Each	×	Hrs. / Day	=	Wh / Day	×	Days / Wk.	÷ 7 =	Avg. Daily Wh
Laptop computers	12		30		4.00		1,440.00		7		1,440.00
Schneider XW6048 inverters	1		40		24.00		960.00		7		960.00
Chest freezer, 10 c.f.	1		–		–		740.00		7		740.00
Modem/routers	5		6		24.00		720.00		7		720.00
Lights: personal	12		15		4.00		720.00		7		720.00
Room fans	10		10		6.00		600.00		7		600.00
Washing machine	1		750		0.75		562.50		7		562.50
Small refrigerator	10		–		–		5,000.00		7		5,000.00
Phones	10		2		24.00		480.00		7		480.00
Lights: group space	4		23		4.00		368.00		7		368.00
Range hood lights	10		18		1.50		270.00		7		270.00
Blenders/food processors	10		350		0.10		350.00		5		250.00
Battery chargers	10		10		13.00		1,300.00		1		185.71
Car stereos	10		8		2.00		160.00		7		160.00
Circulating pump	1		30		4.00		120.00		4		68.57
Phone/ iPod chargers	10		5		1.00		50.00		7		50.00
Range hood fans	10		18		0.25		45.00		7		45.00
Printers/fax/scanners	10		12		0.20		24.00		7		24.00
Pressure pump	1		30		0.50		15.00		7		15.00
										Total Avg. Daily Wh	12,658.79

Twelve individual kWh meters transmit consumption data to a data logger, helping balance the energy use of residences, the community kitchen, and a diversion-load water heater.

There are no electrical space-heating loads in the neighborhood. Passive solar design and wood heaters provide space heating in each home. Tankless propane water heaters provide water heating in each cabin. Cooking is primarily propane, although some cabins now use electric tea kettles or electric burners for cooking and/or dishwashing on sunny days.

Before the microgrid was installed, the few folks who had refrigerators often had to run generators to keep their batteries charged. Only one household had the ability to run power tools. Now, all households have the ability to run refrigerators, power tools, and other large loads like juicers, tea kettles, cooking plates, and irons. There's more reliable power for all of their small loads. And now there is only one generator, which rarely has to run.

Sharing the Costs & Counting Electrons

An important factor in creating a shared power system is how to fairly split all of the capital and maintenance costs between people who have different impacts on the system. Some homes have larger electrical loads than others. Some users will forgo running large loads in the evenings during cloudy weeks, while others are simply less aware of their electrical consumption. In light of each home's varying impacts on the system, it was essential to figure out how to fairly allocate the costs among the users.

In response, Chris designed and installed a weighted metering system for the Hut Hamlet microgrid to record each household's true impact on the system. This metering system accounts for the fact that drawing energy out of the battery bank while at a lower state of charge (SOC) results in more wear and tear on the bank than using energy when it's fully charged.

The neighborhood agreed to base their monthly maintenance fees and also adjust their initial capital contributions based on the results of the metering. Initial capital contributions were determined by every household filling out an individual electrical loads spreadsheet, based on what their estimated loads would be a year or so after the system's completion. Afterward, each household's totals were summed to derive appropriate percentages.

Each household's circuit is run through a kilowatt-hour meter that sends a pulse for every 1.25 watt-hours consumed to a single BeagleBone Black microcontroller. The microcontroller checks the system's SOC as determined by a TriMetric meter in real-time, and applies a multiplier to each watt-hour based on the SOC. The multiplier is 1x for 100% SOC, but 11x for 0% SOC. The multiplier for 50% SOC is 6x. If the generator is running or has run anytime in the last 12 hours, the multiplier is automatically 11x, regardless of the SOC.

The SOC is based on what is available from the battery, instead of the full rated amp-hour capacity. In this case, a HuP Solar One 950 Ah battery was installed. Since the battery bank must not be fully discharged under normal usage, the SOC is based on 630 Ah, which keeps 34% of its capacity in reserve.

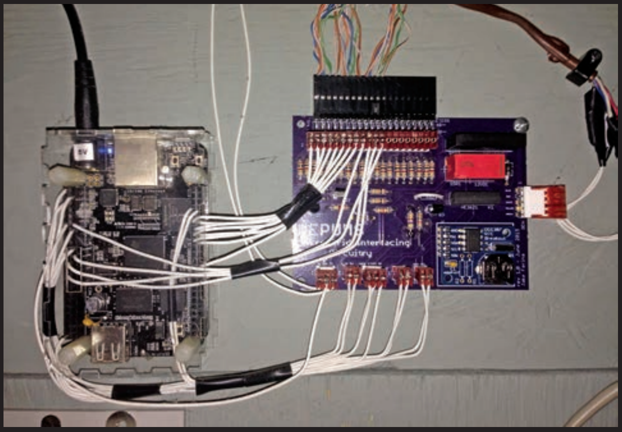
The TriMetric has been programmed for a 630 Ah battery, since that is the capacity readily available to the neighborhood. When the TriMetric reads "Minus 630 Ah" (or any larger number), this registers as 0% SOC; negative 315 Ah registers as 50% SOC; negative 157 Ah registers as 75% SOC; negative 63 Ah registers as 90% SOC; and so on.

A simple algorithm calculates the multiplier factor from the SOC percentage. The multiplier is a perfect gradation, by percentage points, between 11x (for 0% SOC) and 1x (for 100% SOC). For example, 10% SOC has a multiplier of 10x, 20% is

BeagleBone Black Microcontroller

Microcontrollers are small, affordable computers (~$55 for the BeagleBone Black) with many digital or analog input and output ports that can be used for a diversity of projects. With Ethernet, USB, and serial port connections, they can communicate with many other devices and the Internet. They can be used as programmable logic controllers (PLCs), to run, monitor, and record many types of industrial processes. Whereas PLCs are usually programmed in some more user-friendly form of ladder logic, microcontrollers are programmed in common C, C+, or C++ computer languages. Microcontrollers are cheaper and more versatile than PLCs, but do require a computer programmer.

Chris designed the weighted metering system, and the automatic generator start (AGS) program. Former Earthaven resident Jake Ferina wrote all of the computer code for the microcontroller and also designed a custom printed circuit board that serves both the weighted metering and AGS systems. These programmed microcontrollers are available from Chris for other communities that also want weighted metering systems.



Hut Hamlet Example Monthly Weighted Usage (September 2015)

Energy Use	Tribal Condo West	Tribal Condo East	Kitchen	Water Heater	Yurt-goslavia	Tudor Hut	Snake Hut	Micro Hut	Zen Hut	A-Frame	Flower Hut	Wonky Hut
Meter kWh	9.70	67.25	13.39	228.14	16.97	86.57	2.13	6.73	6.68	44.07	4.88	34.44
% of kWh	1.9%	12.9%	2.6%	43.8%	3.3%	16.6%	0.4%	1.3%	1.3%	8.5%	0.9%	6.6%
Weighted %	2.5%	16.8%	3.3%	25.8%	4.4%	21.6%	0.5%	1.7%	1.3%	10.4%	2.8%	8.8%

Double Check												
Pulses count	7,896	54,487	10,879	194,023	13,744	70,715	1,783	5,471	5,441	36,384	3,590	27,795
Pulse kWh	9.87	68.11	13.60	242.53	17.18	88.39	2.23	6.84	6.80	45.48	4.49	34.74
Pulse kWh % of meter kWh	101.8%	101.3%	101.6%	106.3%	101.2%	102.1%	104.6%	101.6%	101.8%	103.2%	92.0%	100.9%

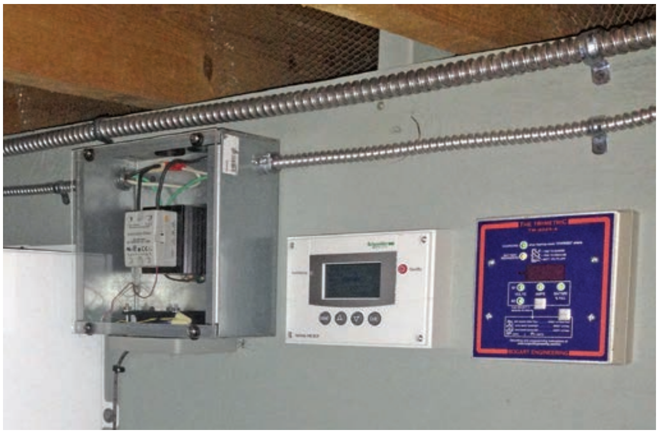
Thirty-two 255-watt Kyocera modules in eight series strings. The two subarrays are offset in relation to a road behind them, not for solar exposure purposes.

9x, 30% is 8x, 40% is 7x, 50% is 6x, and so on, up to 100%, which is 1x. It works down to the single percent accuracy of SOC, not just for every 10% (45% is 6.5x; 49% is 6.1x) Each hour, the microcontroller totals all of the weighted pulses for each household and records the data. Once a month, the data file is downloaded onto a laptop computer and inserted into a spreadsheet to calculate the monthly weighted impact for each household. The microcontroller also provides a count of pulses for the month, so that the pulses can be double-checked against the kWh meter displays.

A diversion-load relay (at left), controlled by a MidNite Solar charge controller, diverts excess solar energy to a water heater in the common area.

In the middle, a Schneider Electric system control panel for remote control and monitoring of charge controllers and inverters.

A Bogart TriMetric amp-hour meter sends battery state-of-charge data to the data logger.



Tech Specs

Overview

System type: Off-grid, battery-based solar-electric

Date commissioned: June 2015

System location: Black Mountain, North Carolina

Latitude: 36°N

Solar resource: 4.89 average daily peak sun-hours

Production: 945 AC kWh per month

Photovoltaics

Modules: 32 Kyocera KD255GX-LFB2, 255 W STC, 30.4 Vmp, 8.39 Imp, 37.6 Voc, 9.09 Isc

Array: 8,160 W total; two subarrays of 16 modules—each four strings of four modules is 121.6 Vmp, 1,020 W STC total

Array combiner boxes: MidNite Solar MNPV12-250s with MidNite Solar 300 V 15 A DIN rail breakers

Array disconnect: MidNite Solar 300 V 60 A panel mount breaker (located in the XW power distribution panel) for each array

Array installation: IronRidge ground-mount, one array faces 180°; one is 170°, both tilted at 40°

Energy Storage

Batteries: Four HUP Solar One, SO-6-85-19, 12 V 950 Ah each; 950 Ah at 20-hour rate, flooded lead-acid

Battery bank: 48 VDC nominal, 950 Ah total

Battery/inverter disconnect: One 250 A breaker per inverter

Balance of System

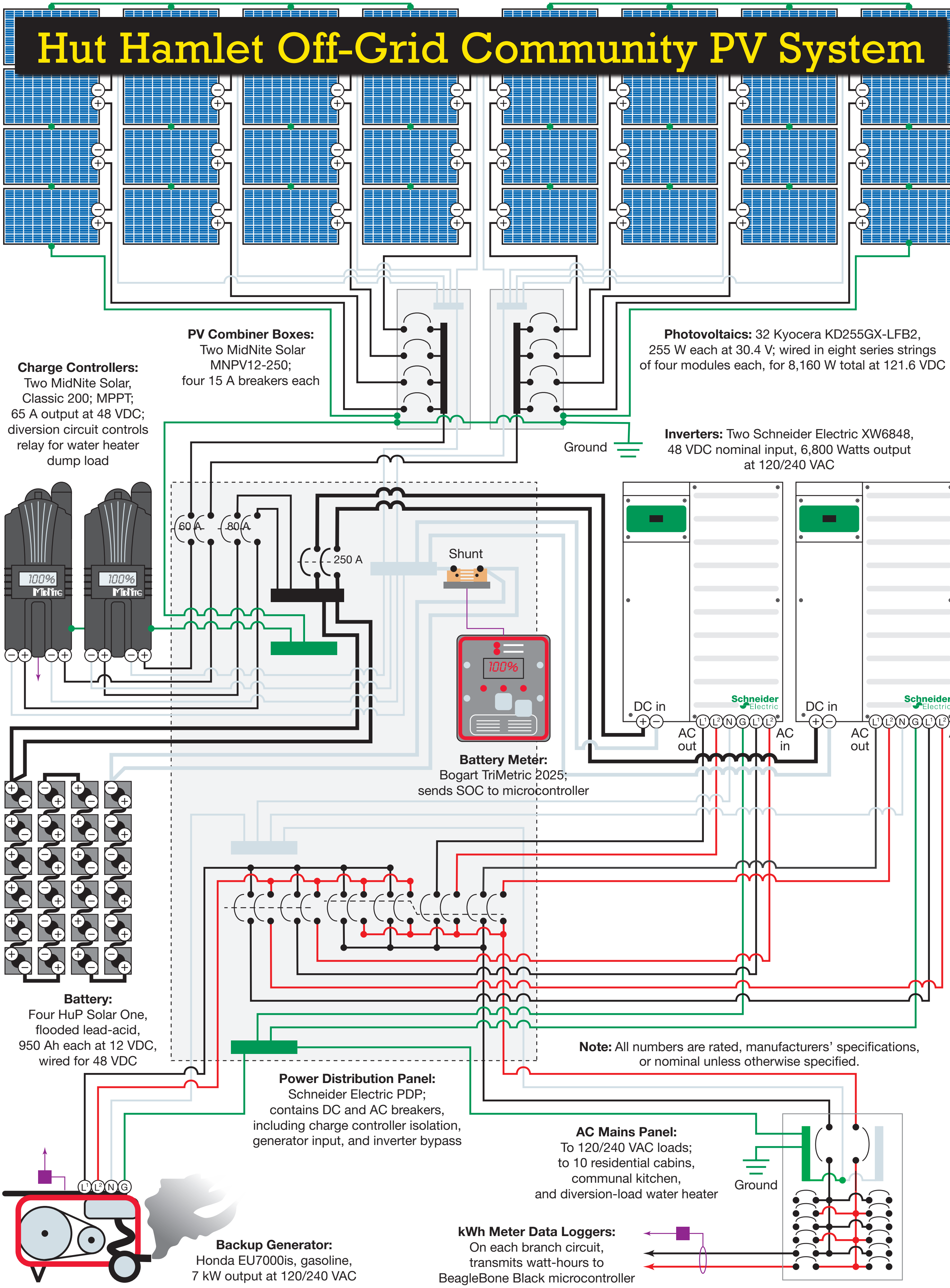
Charge controllers: Two MidNite Solar Classic 200, 200 VDC max input, 121.6 Vmp MPPT input voltage, 65 A at 48 VDC nominal output

Inverters: Two Schneider Electric XW6848, 48 VDC nominal input, 120/240 VAC output

System performance metering: 12 EKM-251DS kWh meters, BeagleBone Black microcontroller, Bogart TriMetric 2025 and Schneider Electric system control panel

Backup generator: Honda EU7000is gasoline, 7 kW, 120/240 VAC

Hut Hamlet Off-Grid Community PV System



A MidNite Solar Classic 200 MPPT charge controller for each PV subarray. One controls a relay for the water heater diversion-load circuit.

Maintaining a Shared System

A 7 kW Honda EU7000is generator turns on with an automatic generator start (AGS) system programmed into the microcontroller. This AGS only requires that the neighborhood residents regularly check the level of fuel in the generator's tank. If, after a few seconds, the generator is not yet on, the AGS stops. It tries again after 5 minutes. After several attempts, it will take an even longer break and then completely start over. The generator battery is on a trickle charger, so theoretically, the generator will keep attempting to start until someone finally hears it trying to start, and figures out that it needs gas. The neighborhood residents are fully informed that this is their biggest responsibility for maintaining the whole system (and for preventing a low-voltage disconnect from the inverters and a full system shutdown). If the battery stays above 57.6 V for more than two hours, the generator automatically turns off.

Every month, maintenance bills are sent to each user based on the weighted metering data. After two years, the user's original estimate for their percentage of impact on the system (and therefore for their original capital contribution) will be re-evaluated. All users have agreed to adjust their original capital contribution in light of the weighted metering data. Any discrepancy between their original estimate and actual usage will be reflected over time on the user's monthly bill as either a fee or a refund.

So far, everyone's weighted metering percentage has been surprisingly close to their actual energy consumption percentage. This means that everyone in the neighborhood has a relatively similar level of consciousness around the timing of their electrical consumption and that they throttle back their consumption as the batteries get increasingly drained. It is assumed that the weighted metering system encourages a high level of consumption consciousness.

Four HuP SolarOne flooded lead-acid batteries supply 950 Ah at 48 VDC—enough storage for the whole neighborhood.

Maximizing Trenching Benefits

The microgrid required about 900 feet of trench through the neighborhood, starting from the main kitchen/bathhouse, where the battery and BOS are located, to each home. Since this excavation was already disruptive to the landscape, the neighborhood decided to also use the trench to replace other infrastructure.

The Hut Hamlet neighborhood had grown in a rather hodge-podge fashion, which left phone lines trenched through the neighborhood in very nonlinear ways. These phone lines were often accidentally cut, which was annoying to both the neighborhood and to the local phone service provider.

A new master cable was run to a pedestal near the central power distribution point. The phone company supplied new phone cable that was run to each home in the same trenches as the power lines (separated by at least 12 inches). This centralized phone and power distribution allowed a neighborhood Internet network to be created, providing high-speed Internet to every user of the microgrid. The neighborhood previously had only four DSL connections, with the phone company not offering any more—the remaining hut owners were simply out of luck.

With centralized phone lines, the neighborhood was able to pool the four DSL connections in one spot, run each phone line into its own DSL router, and then run all into a load-balancing router. This router was then plugged into an Ethernet-over-powerline adapter at the power distribution point, which sends Internet signals along the power lines to the homes. Surge-protection was placed on the four individual DSL phone lines, and the Ethernet-over-powerline connection.

Now, wherever there is a power outlet on the microgrid, someone can plug in another power line adapter to access high-speed Internet service. This may not seem like a big deal to many people in the modern world, but living in the middle of nowhere, it's quite an improvement.

Two situations can trigger the generator to turn on during daylight hours:

- When the battery drops below 50% SOC and the SOC has not reached 100% in the past seven days
- If the battery drops below 25% SOC and the SOC has not reached 100% in the past four days

If the battery drops to 0% SOC, the generator automatically turns on, regardless of the history or the time of day.

Monthly bills to each user include costs for regular monthly maintenance so that a qualified person (currently, Chris) can check the system, equalize and water the battery, and perform generator maintenance. The monthly bills also include costs for accounting and for the depreciation of the entire system. Additionally, the Hut Hamlet Co-op is generating a capital fund to purchase replacement equipment when needed.

Ownership

Originally, the neighborhood wanted to own the PV system outright, instead of creating a separate entity to own the system and sell energy to the users. The group also wanted each user to be able to own differing amounts of equity in the system and take advantage of available renewable energy tax credits.

However, the issue of renewable energy tax credits forced the group to develop an appropriate legal entity to own the system. Only condominiums and housing cooperatives can pass through tax credits to their members without triggering "passive activity loss" rules with the IRS. These PAL rules state that "passive" tax credits can only be used against tax liabilities derived from "passive" income, which is narrowly defined as either rental income or income from businesses one owns but in which one doesn't actively engage (stock earnings are not included as "passive" income).

Given this situation, the users would have been ineligible to use the tax credits unless they legally formed as a housing cooperative. Fortunately, the Hut Hamlet neighborhood at Earthaven was already beginning to legally form a housing cooperative, which now owns the microgrid officially.

Organizing the Group

The Hut Hamlet hired one of its residents to facilitate the microgrid's development—to organize and schedule meetings, take and post minutes, and keep track of any unresolved issues that needed the group's attention. The neighborhood also hired legal and accounting consultants to advise on all questions involving legal entities and taxes.

The neighborhood simply added the cost of these services to the system's total capital cost, which was then allocated to users based on each household's estimated percentage of impact on the system. The weighted metering system allows these original estimates to be adjusted over time with real-world data so that everyone pays for their fair share of the system and its associated costs.

Putting Surplus Energy to Good Use

A question in any off-grid solar design is how large a battery bank to install relative to the PV array size. Too small and it's almost useless, meaning there's not enough stored energy to get you through the night or a cloudy day. Too big for the PV array, and the batteries will not adequately recharge after cloudy spells, and be in a discharged state for longer periods, reducing their longevity.

The battery was sized to give two full days of autonomy. Under no modification of consumption by the households, the depth of discharge (DOD) will likely reach 80%. If the households are in "conscious conservation" mode, the batteries DOD won't be as large—about 60%.

Hut Hamlet PV & Water Heating Systems Materials Cost

PV System*	Cost
4 HuP Solar One SO-6-85-19 12 V, 950 Ah batteries	$11,200
32 Kyocera PV modules, KD255GX-LFB2, 255 W	7,680
2 Schneider Electric Conext XW6848 inverters	6,181
Honda EU 7000is generator (not eligible for federal tax credit)	4,000
IronRidge XR racks	2,737
Schneider XW power distribution panel, connector kit, breakers	1,912
Miscellaneous electric; wire, fittings, conduit	1,480
2 MidNite Solar Classic 200 charge controllers	1,281
Shipping	1,000
10 pipes for ground mount, 2 in. schedule 40, 21 ft.	800
Concrete & rebar for footers	700
HuP battery watering kit & tank	476
4 MidNite Solar surge protectors	356
Cables for battery & inverter, 4/0	345
MidNite Solar MNPV12-250 PV combiner boxes	337
MidNite Solar breakers	332
Battery box materials (plywood, EPDM, screws, vent)	200
Automatic generator starter, custom	150
Battery pickup	150
Bogart TriMetric 2025	145
Post-hole auger rental	100
Shunt bus, to parallel 4/0 battery negative cables through shunt	28
DC Shunt 500 A 50 mV for battery	24
Total PV System	$41,614
Federal Tax Credit	-12,484
State 35% tax credit	-14,565
Grand Total, PV System	$14,565

PV Hot Water Diversion System	Cost
Marathon Lifetime water heater, 105 gal.	$1,300
Miscellaneous diversion electrical	539
Miscellaneous plumbing & other electrical	500
Mixing valve for water heater	135
Azel dual thermometer for water heater	70
Drain pan for water heater	45
SSR & heat sink enclosure (metal screw top box w/ plexi cover)	30
General miscellaneous	500
Total Hot Water Diversion System	$3,119
Federal Tax Credit	-936
State 35% tax credit	-1,091
Grand Total, Water System	$1,092

*PV system only, excludes items for distributing & monitoring individual huts

A large array can keep the batteries well-charged and provide quick recharging after cloudy spells, but electricity may be "wasted" during sunny weather—once the batteries are charged, the solar charge controller will disconnect the array to prevent overcharging the batteries.

The two 4 kW arrays were sized to max out the two MidNite Solar charge controllers and to fill out each of the two ground-mount arrays with 16 modules each. To take advantage of any excess generation, a diversion system redirects the array's excess electrical production to a conventional electric water heater, located in the kitchen/bathhouse, which provides hot water to the kitchen and bathroom sinks, a shower, and a bathtub. This provides the neighborhood with a freeze-proof solar water heating system, and essentially gives them two solar systems—a solar-electric and a solar hot water system—in one.

The Hut Hamlet's PV system diverts excess PV energy to a Marathon 105-gallon 240 VAC electric water heater. The water heater is turned on and off by a 240 VAC solid state relay. The relay's DC coil is controlled by the 12 VDC output from the MidNite Solar Classic charge controller's auxiliary terminals. The relay can turn the water heater on and off many times a second, and the inverters are robust enough to handle the loads. The auxiliary output is not triggered by a constant voltage setpoint, but instead by the in-the-moment charge setpoint—which differs, depending on the battery's charging stage (bulk, absorb, float, or equalize) and battery temperature. The diversion starts at 54 V when the battery is in float, but starts at 58.4 V when in absorb, and even higher when in equalization.

The water heater's thermostat is set at its maximum temperature (150°F) to store as much excess energy as possible, providing some hot water for showers and dishwashing through the night and into the next morning. (The Marathon tank has 2.5 inches of insulation, so there's very little standby loss.) The water heater uses a mixing valve to temper outlet water with cold water to prevent scalding water from reaching fixtures.

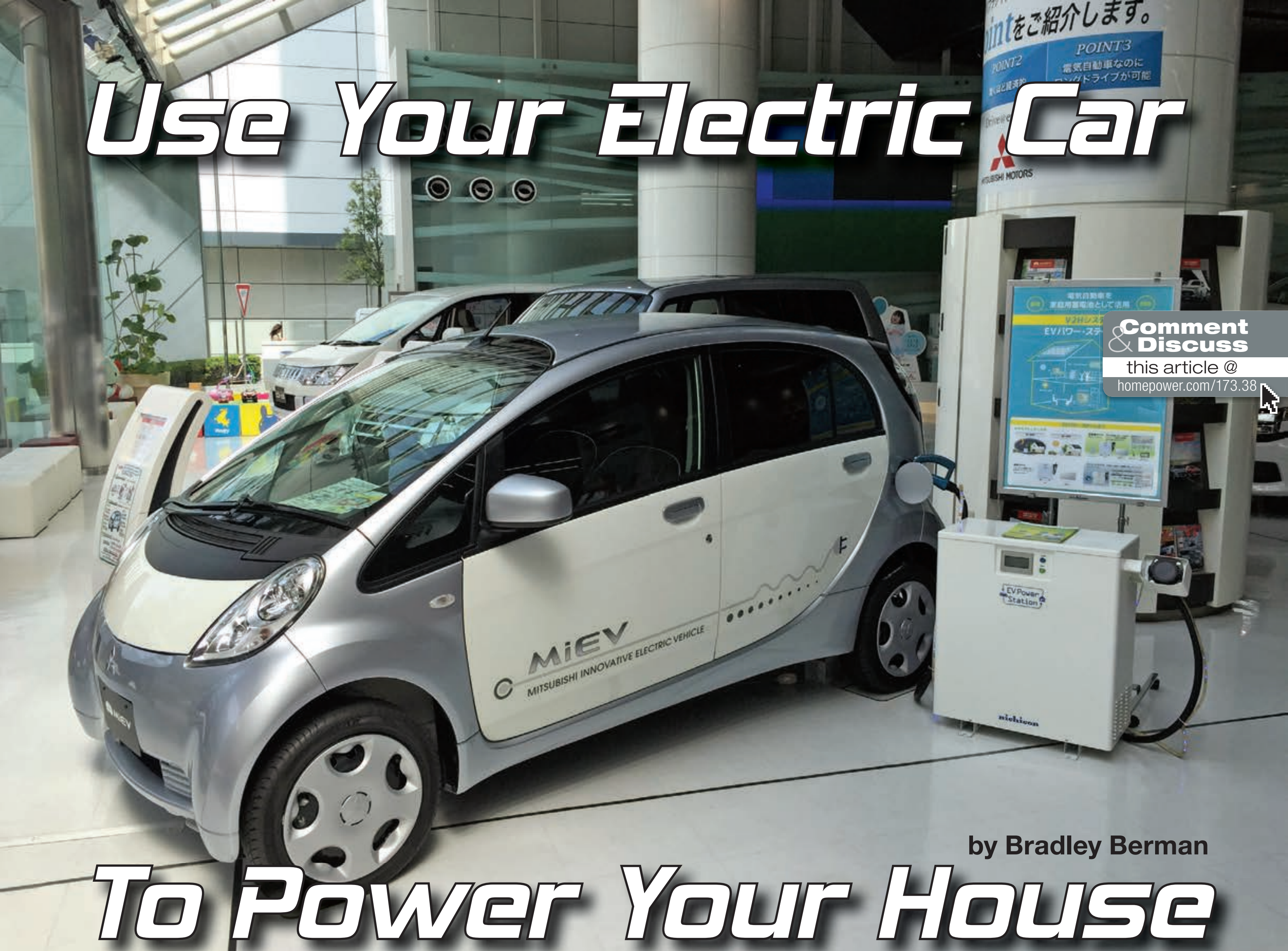
The neighborhood kept their existing tankless propane water heater as backup to the solar-electric water heater. Fortunately, they already had a model that can take pre-heated water as an input. The solar water heating system is freeze-proof, as there isn't any exterior plumbing.

Energy Futures

The Hut Hamlet microgrid is completely solar-powered at this time, but future plans are to incorporate a microhydro system if it takes on new members with additional electrical loads. The neighborhood has a good hydro resource (three different upstream hydro turbines serving other homes are each making more than 500 watts, continuous). Even one turbine could produce about 12 kWh a day—regardless of cloudy weather. A hydro plant's continuous output would be incredibly helpful getting the neighborhood through cloudy stretches when there's little or no PV input.

Before the microgrid, many Hamlet residents had barely enough electricity for a light and a laptop. The new plan, which took many months and many minds to work out, has been running smoothly—and the future of power in the Hamlet looks bright!

Use Your Electric Car To Power Your House



by Bradley Berman

Talking with Mitsubishi Motors Engineer David Patterson

With onboard energy storage, electric vehicles have the potential to serve as a backup energy source during grid outages.

March marked the fifth anniversary of Japan's catastrophic 2011 earthquake and tsunami—a disaster that tested a society's ability to switch to different power sources. For example, battery-powered electric vehicles (EVs) were a transportation boon at a time when conventional fuel was unavailable. Technology quickly developed to tap EV batteries to power appliances.

The implications go beyond disaster needs. Even in everyday situations, "power-take-off"—also referred to as bidirectional EV energy flow—could provide a solution for managing peak versus off-peak grid energy consumption and availability, and for greater utilization of renewable energy, especially residential PV production.

After the earthquake, a number of related commercial products emerged in Japan. I spoke with David Patterson, a California-based Mitsubishi Motors R&D engineer who works on powertrain and emissions research—and is a leading proponent of EV power-take-off technology—to learn about the prospect of using EV batteries to power U.S. homes.

Home Power (HP): What was your first involvement with using power from an electric car's battery in a building?

David Patterson (DP): It goes back to the March 2011 earthquake and tsunami in Japan. Mitsubishi Motors brought its i-MiEV electric car into the disaster areas for people to use for transportation. [Because of the difficulty of fossil fuel resupply], EVs were easier than gas cars to refuel. Our engineers pondered the idea of how to make this power available for homes, and they came up with the MiEV Power Box.

HP: What's the MiEV Power Box?

DP: The Power Box is a simple inverter. It changes battery direct current to AC to be used in standard appliances. It's similar to stand-alone inverters, and fairly inexpensive. It's about the size of two shoeboxes, and it weighs about 25 pounds. You can put it in the trunk of your car to make

AC energy readily available. The only twist is that there's electronic communication in the unit that does a "CHAdeMO handshake" with the car.

We've taken the idea of the Power Box one step further. Nichicon, a capacitor manufacturer, builds something else for our company, a device called the EV Power Station. It's about the size of a mini refrigerator. With the Power Station, you can supply power to the home, rather than just plugging in one appliance at a time. The Power Station hooks right up to your home's electrical system. There's a transfer switch to transfer home power from utility power and connect it to the Power Station. Essentially, it hooks up and functions exactly like a backup generator, with all the same protections against "backfed" power.

However, there's only so much energy in the car battery pack, so it will only last so long. Therefore, it would not be desirable or advisable to power your entire house, but rather just critical loads.

HP: CHAdeMO is a standard for quick-charging electric cars, specifying the coupler that puts high-voltage power into EV batteries. Can you give us more details on the link between the EV and the Power Box?

DP: The Power Box uses the same CHAdeMO plug-in, fast-charging protocol, providing communication between the charger and the vehicle—which is key. The vehicle and the charger communicate and identify one another. When you plug in the MiEV Power Box, the car knows what's being plugged in, and the car closes the main contactors. This sends DC power to the Power Box, which can be used in a single plug-in appliance. In Japan, it's sold retail and can be used with the Mitsubishi Motors i-MiEV, Nissan Leaf, Kia Soul EV, and the Toyota Mirai fuel-cell car.

HP: Do you envision a time when the MiEV Power Box or the EV Power Station—or both—will be offered in the United States?

DP: I do, but I'm not sure when. I could see the products here in about five years, given development and regulation needs.

HP: What's the demand for these products?

DP: The numbers aren't big yet in Japan, but it's starting to take off. Remember, there's still a relatively small EV market there. But this is where it gets interesting. The technology that's in the power station is basically the same inverter technology that PV inverters use—they change high-voltage DC electricity to usable household AC electricity—and they are found in many garages or on the sides of many American homes already. The difference is that most PV inverters are only built for one-way power transmission. Take your J1772 240-volt electric car charger and combine the two technologies—that's the Nichicon Power Station. The Power Station can change the DC energy source (from the car's battery) to AC electricity to power loads in a home, and it will also allow the flow of electricity from the grid to the vehicle to charge the car's battery.

While it might seem the Power Station is basically a grid-tied battery-based inverter, it's more analogous to an emergency generator. You would use the EV Power Station in lieu of a gas or diesel generator. The Nichicon products

Courtesy Mitsubishi Motors

The MiEV Power Box was inspired by grid outages that resulted after the March 2011 earthquake in Japan. It allows a single appliance to receive power from the i-MiEV battery pack.

Courtesy David Patterson

What's CHAdeMO?

A CHAdeMO coupler uses high-voltage direct current to charge an EV's battery faster than even the 240-volt on-board charger. CHAdeMO is an abbreviation of "CHArge de MOve," equivalent to "move using charge," according to Wikipedia. It's also a pun. The Japanese phrase "O cha demo ikaga desuka" translates as "How about some tea?"—referring to the time it would take to charge a car.

Courtesy Toyota

Courtesy David Patterson

The Nichicon Power Station provides energy from a Mitsubishi Motors i-MiEV directly to a home's electrical system. Nichicon also makes a similar unit for the Nissan Leaf EV.

are not designed or marketed as a grid-tied solution. For a grid-tied solution, you would need to regulate the power and frequency, which puts you in discussion about vehicle-to-grid (V2G). What we're talking about now is essentially vehicle-to-home (V2H).

These devices are simply and specifically to take energy from a Mitsubishi Motors i-MiEV, Nissan Leaf, Toyota Mirai fuel cell car or any other vehicle with a CHAdeMO port. The amount of energy that is released from the car is controlled by the vehicle's software. The key is the CHAdeMO communications system. The vehicle is controlling the Power Station, which is doing the work of converting DC to AC. The car is telling the Power Station how much energy is being provided, just like it controls the power flow into the batteries with a DC quick charger.

The technology is already there. The question is whether customers want to spend, say, a few thousand dollars for this. How much would you spend to allow your car to plug into your house and use its energy during a power outage? That's what the entire industry doesn't know—is there a market?

When I talk to the utilities in the Northeast, they say there's a huge number of customers who install backup generators in case of an emergency so when they have a utility outage, they have backup power for critical loads.

HP: What typical household loads could be run given the battery capacity of a typical EV?

DP: If the utility grid goes down in an emergency, you would want to use those precious kilowatt-hours for relatively minor loads with the maximum benefit during a power outage: pumps for a well; refrigeration and freezers; and powering your modem/cell phone or other communication equipment. It's all about having an emergency backup for critical loads.

HP: If you want to charge the EV with PV when the grid is down, would the Power Station make this possible? How would that work?

DP: It's theoretically possible with the correct wiring, but this has nothing to do with the current development of the Power Station. Yes, it can double as an EV charging station because of its bidirectional capability. But that's not its primary function, which is to pull energy *from* the car and provide it to the house.

Editors' Note: Mitsubishi Motors is not alone in its development of V2H technology. On the horizon are AC Propulsion's tZero; ConVerdant Vehicle's Plug-Out kit; Honda's Power Exporter 9000; and Toyota's V2H.

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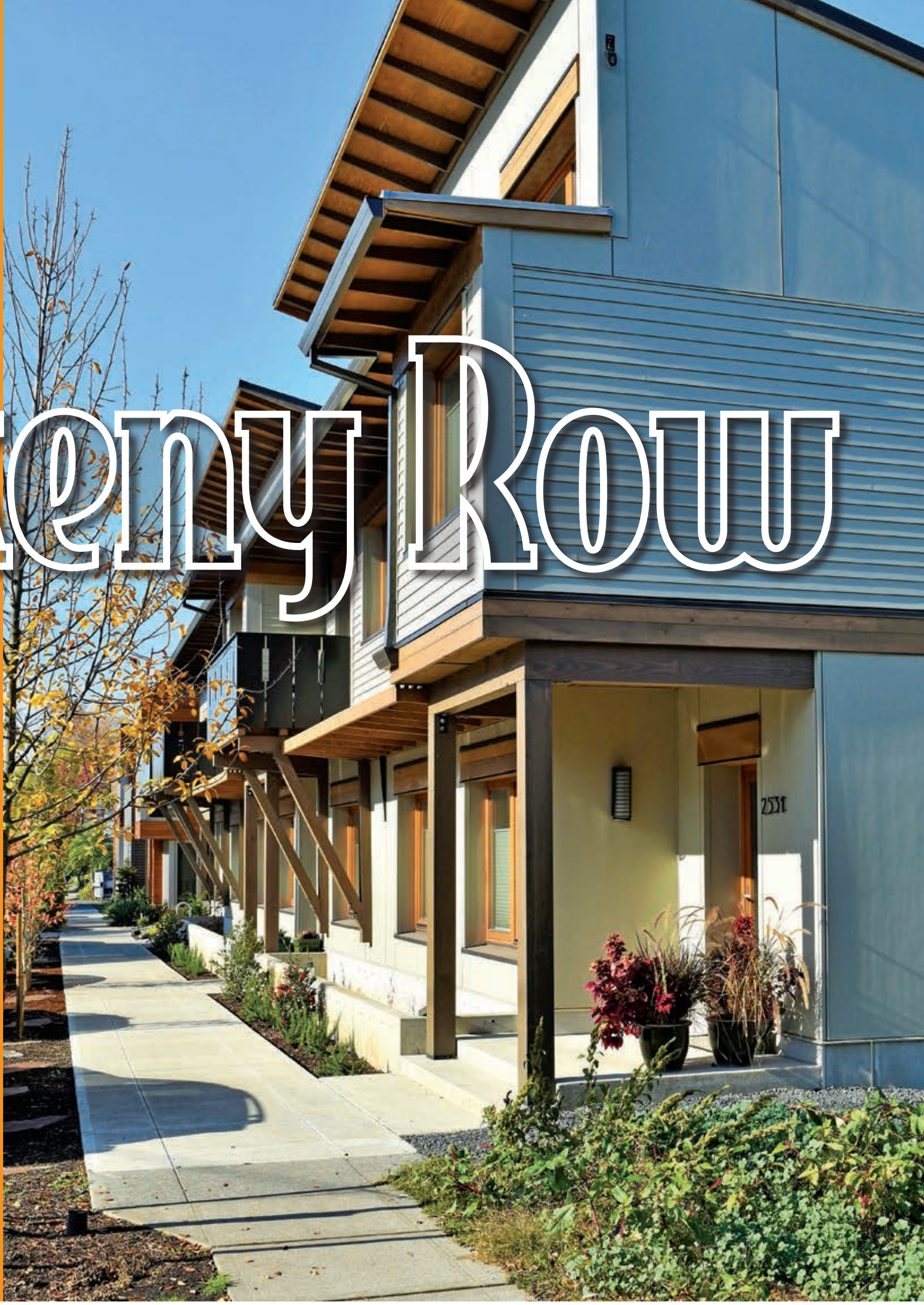
Ankeny Row

A Net-Zero Retirement Community

by Juliet Grable

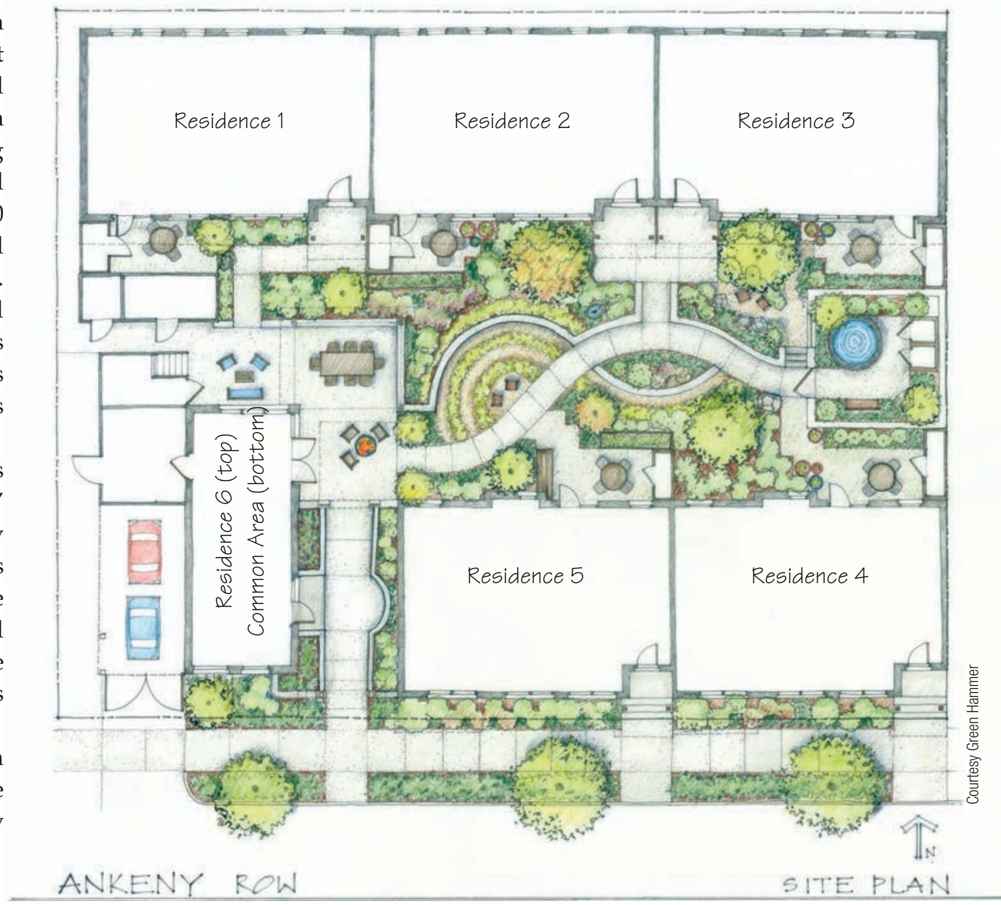

Juliet Grable


Courtesy Green Hammer

When attorney and Green Empowerment nonprofit founder Michael Royce dreamed of the perfect community in which to retire, he envisioned something akin to his childhood neighborhood in Milwaukee, Wisconsin. The 10 townhouses on Ogden Avenue shared walls and a common backyard. Everyone knew each other, and Michael, his brother, and their friends would run in and out of each other's houses. Neighbors sat on their porches and visited until late in the evening.

Today, Michael is one of 11 residents of Ankeny Row, a "pocket community" in the heart of Portland, Oregon. Ankeny Row shares features with Michael's old Milwaukee neighborhood. The townhouse-style units share walls and a common courtyard. Residents are both neighbors are friends. Parking is conspicuously absent.

But Michael and his wife Francie, a former city planner, didn't just stumble upon this idyllic community. They helped create it.



Courtesy Green Hammer

Landscape architect Erin Muir of The Figure Ground Studio was hired to make sure the buildings were well-integrated with the rest of the site, and that it included both private nooks and public gathering places. Her design included a winding path that leads from the common room's patio and terminates at what was to be a shared spa garden. All paths and patios are wheelchair-accessible. Muir also had to meet the city's requirements for dealing with stormwater, which she ultimately solved by integrating deep stormwater planters throughout the site.

The five Craftsman-style two-story townhouses that make up Ankeny Row cluster around a central courtyard. A 500-square-foot common room, which includes a kitchen and open dining/entertainment area, is available to residents for meals and gatherings.

Juliet Grable (3)

Juliet Grable (2)

Dick and Lavinia's kitchen and dining area. No two units are quite the same in layout or interior design and finish.

Creating (More Sustainable) Community

The seeds of Ankeny Row were sown in 2004, when the Royces began brainstorming with friends Lavinia Gordon and her husband Dick Benner. All longtime Portland residents, they shared the desire to downsize and create a different kind of retirement community—one that kept them engaged in their neighborhood and supported their active lifestyles. Their vision aligned with the urban cohousing model: small, super-efficient dwellings, with a shared green space and a common room, set in a vibrant, walkable neighborhood. They couldn't find exactly what they were looking for, so they decided to create it.

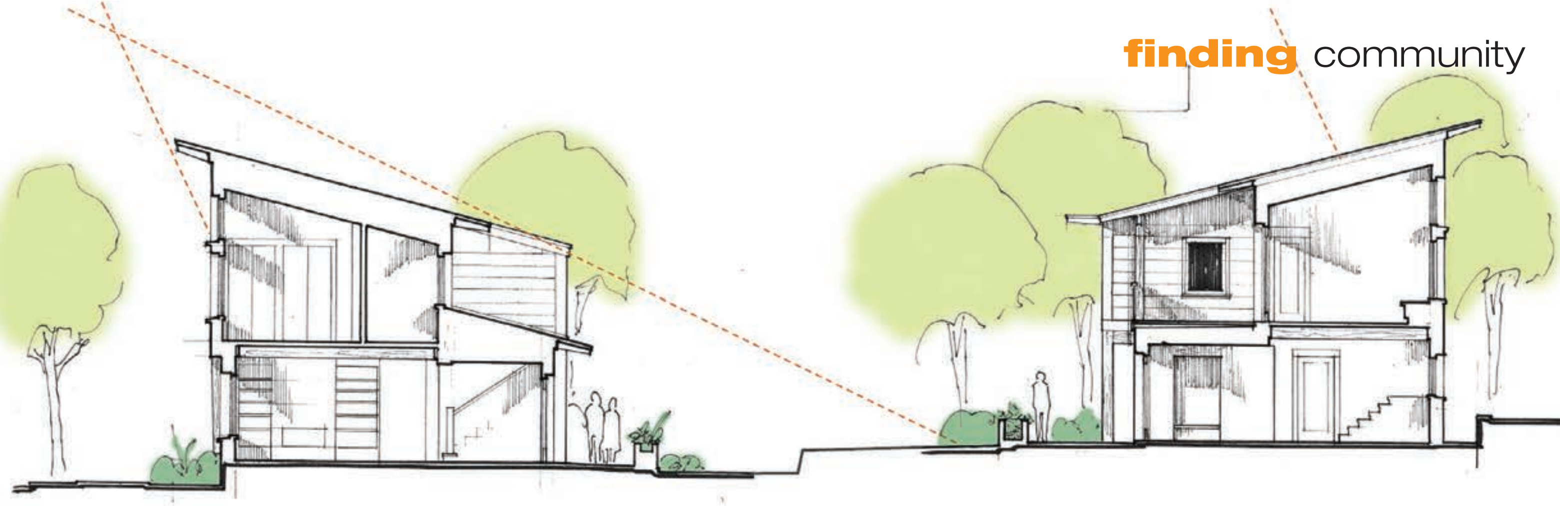
Their backgrounds (law and city planning) helped them navigate the challenges of buying land, setting up a limited liability corporation, and marketing their vision. In 2010, Lavinia's daughter Sarah was riding her bike down a street in southeast Portland and noticed a "for sale" sign on a vacant lot. The location was ideal: in a neighborhood populated by cafes, brewpubs, markets, and a historic theater. Its "walk score"—a measure of how easy it is to get around without a car—is 87 out of a possible 100, qualifying it as very walkable. Portland was still climbing out of the recession, and the lot was priced well. It included an easement to an adjacent industrial site with an ailing warehouse. The group purchased both lots, doubling their canvas to 12,600 square feet.

"As our thinking gelled, we knew we wanted Passive House construction," says Michael. They wanted to rely on the envelope for principal energy efficiency, as opposed to relying on systems.

"My concept of Passive Houses was that they were blocky buildings with small windows," says Benner. "But I was struck by a Passive House in rural New York, which had large windows and just skewered that notion."

Although the group held the vision for green community, they knew that they needed professional assistance to develop it. By the time Francie called Green Hammer, a Portland-based design/build firm, she and her partners had already interviewed 12 architects. The firm impressed the partners with their commitment to sustainable design. Green Hammer specializes in Passive House construction, and their staff includes four certified Passive House consultants.

Francie and Michael's bright and cozy living room area is appreciated by their dog Winston, too.



The community layout was designed with solar exposure in mind. The north row of houses is even terraced 18 inches higher.

Right: The slab foundations are set on 9 to 16 inches of EPS insulation for R-37.8 to R-67.2.

Left: Two-by-four framed walls are combined with 9.5-inch I-joist trusses. The cavities Filled are filled with dense-pack cellulose insulation, creating R-45 walls.

Right: Roof cavities have 30 inches of loose-fill cellulose insulation for R-100 ceilings.

Courtesy Green Hammer (4)

The Green Team

With his contemporary Craftsman style and his commitment to New Urbanism, Green Hammer architect Daryl Rantis was the ideal person to lead the design. Rantis was tasked with balancing the Passive House standard with other design goals, which included creating connectivity among the individual units and complementing the existing neighborhood.

"Daryl was also a firm believer in the relationship between public and private life," says Stephen Aiguier, Green Hammer's founder and CEO. "His design reflects this—the ability to connect with neighbors, but also hide yourself away."

Dylan Lamar, architect and certified Passive House consultant for Green Hammer, worked with Rantis on the design. Lamar provided energy modeling so that they could immediately understand how the design impacted energy performance.

Unfortunately, Rantis died of a heart attack just as the design and development phase was wrapping up. Lamar took the design to completion.

Passive House-Inspired Design

Passive House design uses passive solar siting and airtight, super-insulated envelopes with carefully balanced glazing ratios to optimize energy performance.

Two rows of dwellings—a block of three units in the back, or north and a block of two units in the front, facing SE Ankeny Street—are set along an east-west axis, with a central courtyard in between. A third building in the southwest corner of the property includes an 800-square-foot residence above the common space. The three back units share walls, as do the front two, which boosts the efficiency of the buildings. The site was graded so that the north units are elevated 18 inches above the south units, which allows more sunlight into the north units in winter.

The buildings have slab-on-grade foundations, mostly to facilitate accessibility for the residents. The design called for 8 inches of expanded polystyrene (EPS) under the slabs, but

Exterior sheathing is DensGlass fiberglass-faced gypsum for moisture protection—it rains quite a bit in Portland, Oregon.

Courtesy Green Hammer (2)

The moisture and air barrier is SIGA Majvest woven polyolefin, which helps keep air leakage under 1.00 ACH 50.

Green Hammer installed 9 to 16 inches of Geofoam, mostly to accommodate the unconsolidated soils. "We used EPS [instead of XPS, or extruded foam] because it has lower global warming potential, but it still contributes to structure," says Aiguier. (Hydroflurocarbons, known as "super" greenhouse gases, are used to manufacture XPS, whereas EPS uses pentane, which is not an ozone-depleting agent.)

The walls are 2-by-4 wood framing with 9.5-inch I-joists attached. The 13-inch-thick cavities are filled with dense-pack cellulose insulation, achieving approximately R-45. To mitigate potential moisture issues, Green Hammer used DensGlass fiberglass–faced gypsum sheathing because it's permeable, mold-proof, and dries rapidly, and they wrapped the buildings with SIGA Majvest weather- and air-resistant barrier. This woven polyolefin, which Aiguier calls "Tyvek on steroids," has been well-tested in Europe. The ceiling is packed with 30 inches of loose-fill cellulose, which gives it R-100.

Triple-pane tilt-and-turn Zola windows allow a high proportion of glazing without overly compromising energy performance. Seventy percent of the glazing is on the south side, with transom-style windows on the north. The north facades of the south units, which face the courtyard, include more glazing and shading than the northernmost building. Interior blinds help regulate gains.

The five townhomes range from 1,450 to 1,480 square feet, but the square footage is not evenly distributed between the first and second stories. "We didn't want 1,900-square-foot homes," says Francie Royce. "We had a lot of space to play with upstairs, so we cut the room sizes down and added balconies."

Rantis used balconies, awnings, and variation of materials to help break up the facades of the buildings without affecting the thermal envelope. Though all of the units are relatively narrow, the front ones are more square, the back units narrower, with larger great rooms.

In part because of these variations, Ankeny Row is not officially Passive House certified, though the buildings came close to qualifying. Certification depends on meeting thresholds for airtightness, space heating energy demand, and primary energy demand. Airtightness is measured with a blower door test, and cannot exceed 0.6 air changes per hour at 50 Pascals pressure (ACH 50). All three buildings tested at 1.00 ACH 50 or better, and the back three units met the threshold for space heating demand.

At some point, Lamar says, the net-zero energy goal became more important. "The biggest story, as I see it, is that these homes are net-zero energy with such a small solar array," he says. The 25.5 kW batteryless grid-tied array, installed by Portland-based Synchro Solar, consists of 78 327-watt E-Series PV modules from SunPower. It only takes up about 30% of the roof area of the north building, yet the residences are performing at net-zero or better so far.

Metal standing-seam roofing was chosen for its durability and ease of attaching a PV system. S-5! clips attach the array without penetrating the roof.

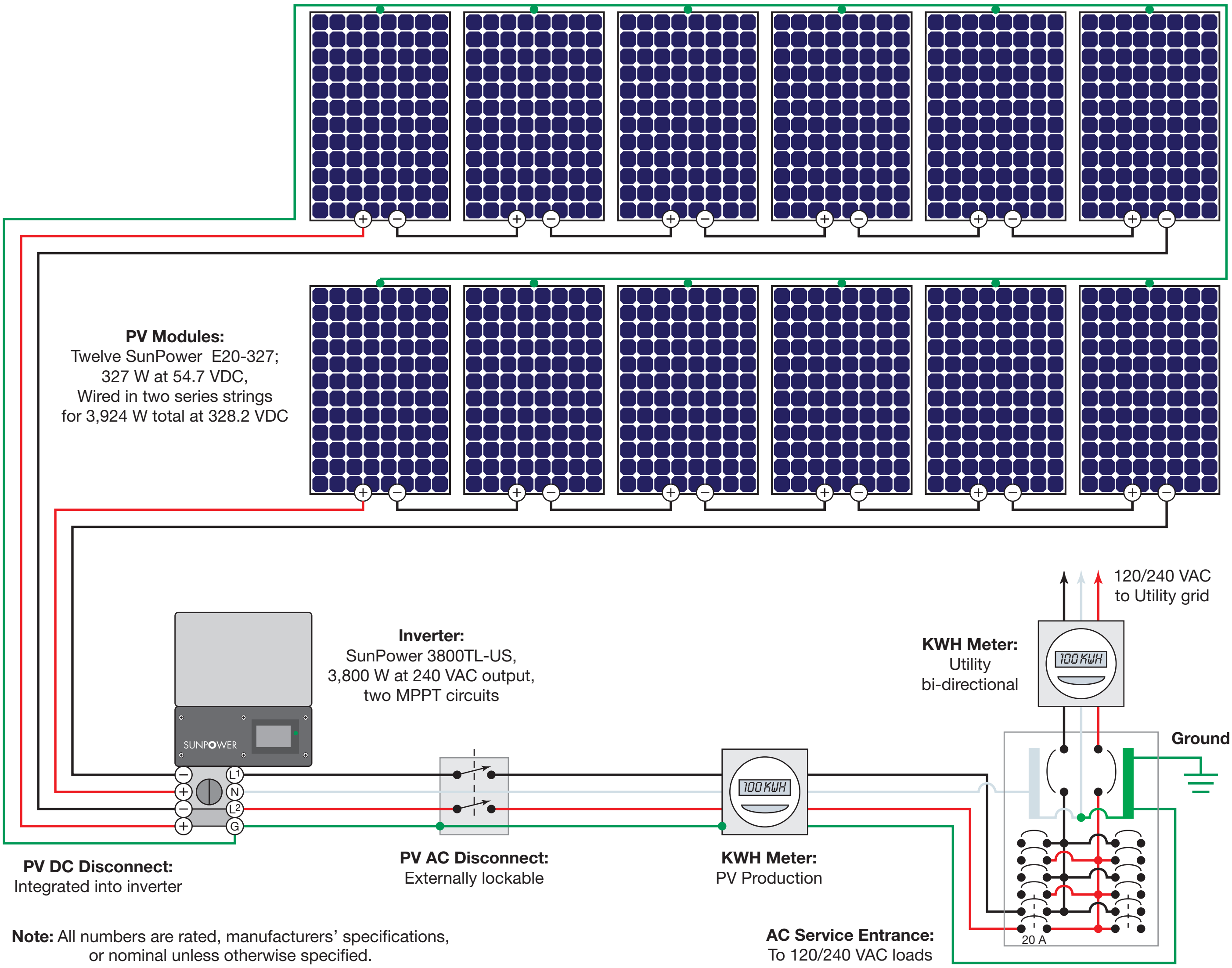
web extras

"Passive Solar Design from a Passive House Perspective" by Katrin Klingenberg in *HP166* • **homepower.com/166.44**

"Breaking New Ground with a Passive House" by Katrin Klingenberg & Mike Kernagis in *HP138* • **homepower.com/138.94**

"The Passive House" by Katrin Klingenberg & Mike Kernagis in *HP138* • **homepower.com/138.70**

Typical Ankeny Row Grid-Tied PV System



Tech Specs

Overview

Project name: Ankeny Row

System type: Batteryless, grid-tied solar-electric

Installer: Synchro Solar

Date commissioned: February 18, 2015

Location: Portland, Oregon

Latitude: 45°N

Solar resource: 4.0 average daily peak sun-hours

ASHRAE lowest expected ambient temperature: 19°F

Average high summer temperature: 89.6°F

Average monthly production: 2,295 AC kWh (estimated, all systems combined)

Utility electricity offset annually: 167% (average for past 9 months)

Photovoltaic System Components

Modules: 78 SunPower E20-327, 327 W STC, 54.7 Vmp, 5.98 Imp, 64.9 Voc, 6.46 Isc

Array: Thirteen six-module series strings, 25,506 W STC total, 328.2 Vmp, 5.98 Imp, 389.4 Voc, 6.46 Isc

Array installation: Unirac mounts installed with S-5! clips on south-facing roof, 20° tilt

Inverters: Six SMA Sunny Boy 3800TL-US, 3,800 W rated output, and one 3000TL-US, 3,000 W; all with 600 VDC maximum input, 175-480 VDC MPPT operating range, 240 VAC output

System performance metering: SunPower monitoring and seven individual production meters

Living Net-Zero

The units are equipped with Mitsubishi minisplit heat pumps, but they have hardly been used. Several of the residents use the ethanol fireplaces for supplemental heat. Because super-efficient buildings reduce heating and cooling loads so drastically, other loads, such as water heating, lighting and appliances, become proportionately greater in energy use. Each residence has a GE GeoSpring hybrid heat-pump water heater. These 80-gallon units harvest heat from the surrounding air to preheat water, making them up to 65% more efficient than conventional tank-style water heaters.

Because the homes are very tight, mechanical ventilation ensures adequate fresh air when windows are closed. Each unit at Ankeny Row has a Zehnder heat-recovery ventilator, which recovers heat from exhausted air in winter and removes heat from incoming fresh air in summer.

The resident-owners are still getting to know some of the systems. For example, the HRV units require some maintenance, including regular cleaning and occasional filter replacement, and the induction cooktops took some getting used to.

Courtesy Michael Royce

Each home has its own PV array, inverter, and production meter. Inverters are SMA Sunny Boy 3800TL-US models rebranded by SunPower.

Juliet Grable

Left: All units have heat-pump water heaters for added efficiency.

Courtesy Michael Royce

Right: Each unit has its own main distribution panel, bidirectional utility kWh meter, and utility-PV interconnection.

Finding Community

After design was completed, the group needed to sell four unclaimed units. Armed with the drawings and six spreadsheets of cost estimates, they approached their closest friends.

"We thought people would be beating down the door," says Michael Royce. "But [at that point], it was still just a concept. We hadn't even broken ground yet." The two couples started talking about a marketing plan, and went so far as to create a flyer, which they distributed to local merchants, but in the end, the couples who bought in were acquaintances or friends of friends.

The townhome-style units are designed to allow the residents to age in place, with open, airy floor plans and bedrooms on each floor. Most couples chose to use the upstairs bedroom as the master, with the option of moving downstairs if they can no longer negotiate the stairs. The upstairs bedroom can also function as a caregiver's quarters.

When it became clear that there would be six unique interiors, Green Hammer hired interior designer Brienne Wasmer of 2Yoke Design to streamline the decision-making process. Wasmer's focus on health also ensured the residents would have high-quality, durable materials and finishes that didn't compromise indoor air quality—from low-VOC paints to wool carpeting.

Michael Royce admits that the degree of customization (along with the rebounding market) drove up the costs. They originally presented the packages, including the land, unit and common area, at $580,000 each. They netted out at around $690,000.

Juliet Grable

Lavinia Gordon and Dick Benner stand in front of their ethanol-fueled fireplace, which is used mostly for ambiance.

At times, the residents are willing to trade efficiency for other benefits. For instance, opening shades in the morning would increase solar gain on a chilly fall morning, but the strong rays can also damage rugs and furniture. Similarly, many of the residents like to keep their windows open all the time, rather than just "night-flushing" the warm air in the evening.

Still, the homes are performing well. "At my 1920s [Portland] house, the total energy bill was around $3,000 a year—and we kept it on the cool side," says Benner. "Here, it will be zero." Benner and Gordon are consuming between 200 and 300 kWh per month. At least three of the units are poised to produce more energy than they consume, with nine-month totals showing excess production between 1,173 and 1,426 kWh.

Since the project was completed, Ankeny Row residents have received several inquiries from people interested in pursuing a similar project. In a nearby neighborhood, a larger-scale 55-and-over cohousing community called PDX Commons is in the works.

"Inevitably, the people who call us want to do 20 units," says Benner. "But I think [limiting it to] six couples makes it feasible." So does affordable land, which is hard to come by in Portland, especially in the desirable core area. The Ankeny Row team benefited from serendipitous timing. Building a medium-density development worked out financially, even though they could have "maxed out" the property with more than 40 units.

Tower Climbing

Tools & Tips from the Pros

Compiled by Ian Woofenden

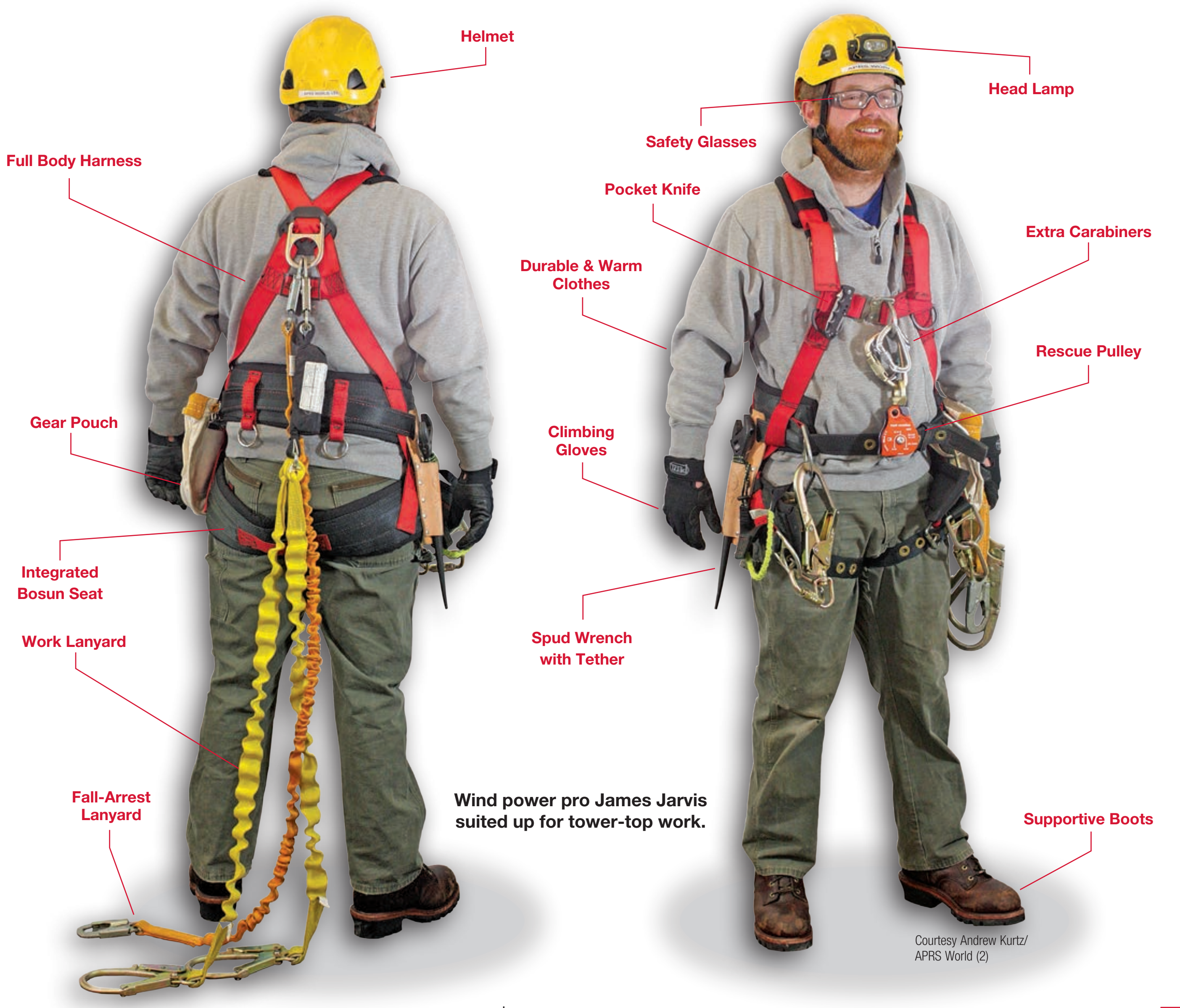
Residential wind-electric systems require tall towers to get above obstructions to the wind—trees, buildings, nearby landforms. High above this "ground clutter" is where the useful wind is, and that's what's needed for good energy production.

And while we may focus on the wind turbine itself as the star of the show, towers are a crucial part of a complete wind-electric system and a major part of the cost and the construction project. Some sites can use tilt-up towers, which allow all installation and service work to be done on the ground. But most wind turbines are atop towers that must be climbed. Normal maintenance for typical residential wind turbines includes inspection at least once a year, but twice a year is better—once before and after the windy season.

Among the climbers of small wind-turbines, I've seen a strong focus on work practices that support safety and comfort aloft. In this article, we'll hear from six experienced climbers, and learn about some of their favorite gear and top techniques for climbing and working on towers—and get some sage advice for aspiring climbers.

A favorite (but not pictured on wind pro James Jarvis, below): Four of the six pros interviewed chose the Petzl Grillon adjustable work positioning lanyard as a must-have tool for up-tower jobs.

Courtesy Petzl



Wind power pro James Jarvis suited up for tower-top work.

Courtesy Andrew Kurtz/ APRS World (2)

Facing page courtesy Gary Harcourt

Roy Rakobitsch

Roy is the owner of Windsine, a company focused on installing PV and wind systems, both on-grid and off. Over the past decade, Roy has been involved with many hundreds of wind installations all over North America, and currently services turbines ranging from 1 kW to 2.5 MW. Roy and his wife live in rural southwest Wisconsin on an off-grid homestead that is powered by wind and sun.

Gear Picks

Dyneema contact slings. I love these things. They are small, light, and many are strength-rated for 22 kiloNewtons of force or greater. I keep a handful of these for rigging and slinging things, such as yaw and pitch motors. They are also great for tool lanyards and lifting heavy cables, since you can easily wind them into a Prusik knot.

Petzl Grillon adjustable work positioning lanyard with Hook connector. This is the best rope positioner I have ever used. It's light, quick to maneuver and adjust, available in many lengths, and can be disassembled for inspection and rope replacement. If the need arises, this positioner can be used in a rescue to suspend or aid in the positioning of a climber. I don't climb without one.

Camp Safety Sphinx rescue pulley. This pulley is relatively small and light (maximum breaking 24 kN), and can aid in a rescue by giving a 2:1 lifting advantage in moving a climber in need of rescue a few inches up or down a rope or ladder so they can be transitioned off their lanyards. It can be installed quickly on the Petzl Grillon positioning lanyard.

A rescue pulley is good for more than just emergencies—it allows changing the rope angle or halving the strength needed to pull loads.

Courtesy Roy Rakobitsch (2)

Roy Rakobitsch in the nacelle of an Endurance E-Series 50 kW turbine, 140 feet up.

Favorite Tower Techniques

- **Be aware.** Keep your eyes and ears open! This is for safety obviously, but you are also there to do a job, so stay alert for things that catch your eyes. Look and listen for things you weren't expecting, such as machinery that sounds odd, an unusual smell, or items like tools and hardware not in the right places. This can be an indication of deeper underlying issues, which may impact your safety or your task at hand.

- **Pace yourself.** Get familiar with your surroundings, but don't get too comfortable or complacent. Don't rush, or push yourself too much. Excessively hot or cold temperatures—combined with long hours (sometimes 10 or more hours up a tower) and sometimes in a very slippery/greasy environment—can take a toll on your body and mind. I carry snacks and water every time I climb.

- **Partner up.** Climb with a buddy, and make sure you can trust your life to him or her. Have a rescue kit at the tower base every time, and pull a rescue rope/descender up-tower whenever you are working, so it will be there, ready for immediate use if needed (seconds count!). I know the folks I climb with can trust me, but you never know who will need rescuing.

Sage Advice

This profession requires a diverse skill set. You need to be both proficient at everyday climbing safety practices and be knowledgeable in the task you are trying to perform, all while working as a team. My advice would be to not only stay current in rescue training, but to practice those maneuvers often, so accuracy and speed can be honed. Know your equipment and your body, and the limitations of both. Practice troubleshooting skills—get as much experience as you can. Eventually, it will make you a better technician and climber. Most of all, have fun! I don't think I would still be doing this if I didn't have a blast on the job.

Jenny Heinzen

Jenny is the training coordinator for the Midwest Renewable Energy Association (MREA) in central Wisconsin, where she oversees and teaches online courses in residential PV and wind power. Before coming to the MREA, Jenny was the lead developer and instructor of the Wind Energy Technology program at Lakeshore Technical College (LTC) in Wisconsin. She's an electrician by trade—working in industry and manufacturing for the first leg of her career, followed by residential wiring and teaching for LTC. Her first tower climb was in 2004, and she's been addicted ever since.


Courtesy Dave Kiedrowski

Jenny Heinzen at tower-top, using one of her favorite pieces of gear—a Petzl Navaho full-body harness.

Gear Picks

Petzl Navaho (replaced by Avao) harness. Tower climbers need harnesses, and this one is my favorite. It's light; padded in the right places; has a woven seat for all-day comfort; and employs self-locking, adjustable straps for a snug fit with a few easy tugs. There are two side D-rings for work positioning, and three gear loops on the waistband for tools, straps, ropes, bags, and carabiners. Instead of a single front D-ring, there are two—one for limited fall arrest, and another for rescue or belay. And my favorite is the V-style, rather than the "standard H" chest, which is not very comfortable for women climbers.

Petzl Grillon adjustable work positioning lanyard. With my Navaho harness, I must have on my left-side D-ring a Petzl Grillon adjustable lanyard. No fuss, no muss—I just wrap the rope around a stable and secure object in front of me, attach the snap hook to my right-side D-ring, and pull to the right length. It's easy to adjust with just one hand and a proper shift in weight. When it's not being used, the tail wraps around itself into a coil and only hangs about 12 inches alongside my leg, free from unwanted ladder or foot-peg snarls and catches.

Slings, straps, short ropes, and carabiners. Variety is good. You can never have too many carabiners or slings on a tower. For hanging tools, securing a rotor, inhibiting yaw rotation, or setting up rope and pulley systems, these items are necessary. Combined with some basic knot-tying skills, a tower jockey can make their job much easier with these simple tools.


Courtesy Roy Rakobitsch

An array of various slings comes in handy for many uses.

Favorite Tower Techniques

- **Pace yourself.** Take your time, it's not a race. Find your comfortable climbing pace and stick with it. Don't feel pressured by those who like to climb fast or show off. Nothing's worse than feeling out-of-breath or too tired to give 100% on a tower. You must be ready for anything at any time—always on full alert. And you can't do that when you're pooped.

- **Use a ground crew.** Although not perhaps as "glorious" as tower climbing, a trained and trustworthy ground crew is essential. Who makes sure your ropes don't get tangled? Who hoists your bucket of tools, grease guns, bottles of oil, and whatever else you need? Who helps in a rescue situation? Ground crew. Be nice to them, treat them well, and work together as a team—because that's what you are.

- **Dress appropriately.** Use good, grippy-soled hiking boots—no steel toes; nothing too bulky. They need to be firm with ankle support. Good gloves are a must—I have multiple pairs that I carry in my gear bag: full-fingered, fingerless, warm weather, cold weather, gloves for climbing, and gloves for working up-tower. Bring break-and-shake hand-warmer packets up-tower—cold fingers with little to no feeling are bad news.

Sage Advice

Trust yourself and know your limits. It's too easy to feel safe because of all the gear we tower climbers wear. But what I always tell first-time climbers (or those who seem to have forgotten) is that all of the fancy, expensive gear is there to catch you in case you fall—you'll likely be injured and hanging in suspension trauma until a rescue team can get you down. It's the last resort, last-chance effort to stop you from plunging to your death. That said, wearing fall-protection doesn't give you superhuman strength or ninja-like agility.

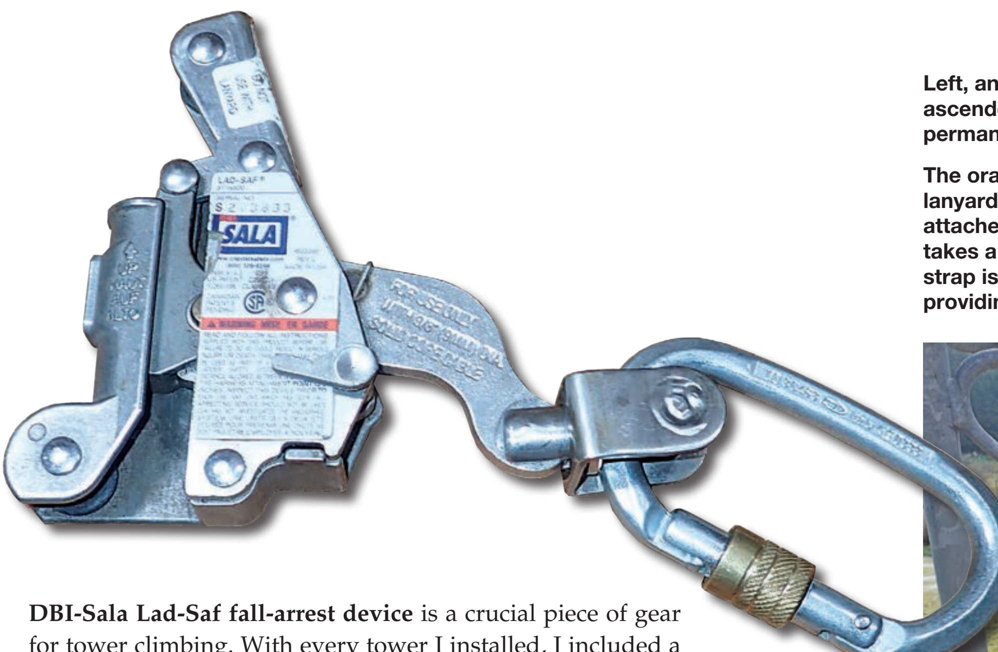
Ian Woofenden

Home Power Senior Editor Ian Woofenden installed his first wind generator more than 30 years ago, and he got the wind power bug big-time. Since then, he's been on all kinds of towers, sharing his enthusiasm and experience with hundreds of students, clients, and others. He authored *Wind Power for Dummies,* and dozens of articles on wind electricity for *Home Power* magazine and other publications. He works from his wind- and solar-powered homestead and office in Washington's San Juan Islands.

Ian Woofenden, high over Washington's San Juan Islands.

Gear Picks

Closeable rope and gear bags are a key part of my tower climbing equipment. I use a variety of sizes for a variety of purposes. Larger bags keep my climbing and service lines clean and safe. Medium-sized bags hold tools and hardware—one particularly handy bag has a rigid bottom and rim. Small bags hold my water bottle and dark chocolate. A tiny bag carries my cell phone, an extra pair of gloves, and a warm hat.



Left, and in use (below): A Lad-Saf cam ascender offers fall protection on a permanently attached, fixed cable.

The orange line is an adjustable positioning lanyard (in this case, a steel-core lanyard), attached through the tower while the author takes a break on the way up. The yellow strap is attached to the author's seat D-rings, providing temporary seated rest.

Ian Woofenden (3)

DBI-Sala Lad-Saf fall-arrest device is a crucial piece of gear for tower climbing. With every tower I installed, I included a fixed cable for use with such a device, so no one climbs the tower without complete fall protection all the time. These fall-arrest devices, common in the large-scale wind world, are easy to use and ultra-reliable.

Lanyards. I carry a variety of lanyards—including at least two adjustable ones—but one particularly handy simple strap lanyard with locking clip has become a favorite. I attach it to my seat D-ring or rings, so it is ready to give me a seated rest on short notice. It is not a primary safety lanyard, and I don't use it alone at any time. But while on the Lad-Saf or another lanyard, I can quickly clip this short strap into a tower girt or foot peg and rest in a seated position, relieving my legs and feet.

Favorite Tower Techniques

- **Use your body well.** While helping and watching dozens of tower climbers, I've noticed that many tend to hug the tower tightly, and use their arms disproportionately. They frequently return to earth with sore arms and shoulders. When I climb, I focus on using my legs—with their larger and more powerful muscles—and I keep my upper body at a comfortable distance from the tower. My arms are more relaxed and take less of the strain, and I can work longer on the tower in comfort.

- **Take advantage of technology.** The advent of cellphones and earpieces allows tower workers to consult comfortably not only with their ground crew, but with other sources of information and advice. More than once, I've been at tower top while on the phone with turbine tech support, or even with the designer of the wind turbine. Smartphones allow photos and other info to be transmitted quickly, and tower time can be reduced with better information transmission. While I also use two-way radios on occasion, and shouting still works in the right conditions, I don't go up a tower without a phone, both for safety reasons and simply to make the job more efficient.

- **Appropriate clothes and positions.** Positioning on a tower can be crucial to efficient work and physical comfort. Multiple factors can make tower work be a breeze or a nightmare. To make it easiest, I like to have comfortable and sturdy boots and a full-body harness with standard and extra rings and clips. I use multiple adjustable and fixed lanyards to hold my body where I want it, without my effort. Trying to do effective work while stretching, reaching, or holding on will wear you out and take more time. Get into a good position where you can fully use both hands before starting to work.

Courtesy Ian Woofenden

Gear bags of various sizes, with drawstring closures, come in handy for ropes, tools and hardware.

Sage Advice

Climbing and heights are not for everyone, but if you want to climb, my advice is to take it slowly. Climb carefully while watching your own hands and feet as you get the feel for the particular tower. Rest frequently—in my tall-tree country, that means about once every 50 to 60 feet of tower, or two to three times on the way up. Tie in, take a breath and a drink of water, and take a look. You'll continue climbing with more energy and awareness. Talk about what you are going to do before you do it. Saying it out loud can help you and your tower mates stop you from doing something stupid or assist you in doing something better. Think before you do, and work predictably.

Gary Harcourt

Courtesy Gary Harcourt

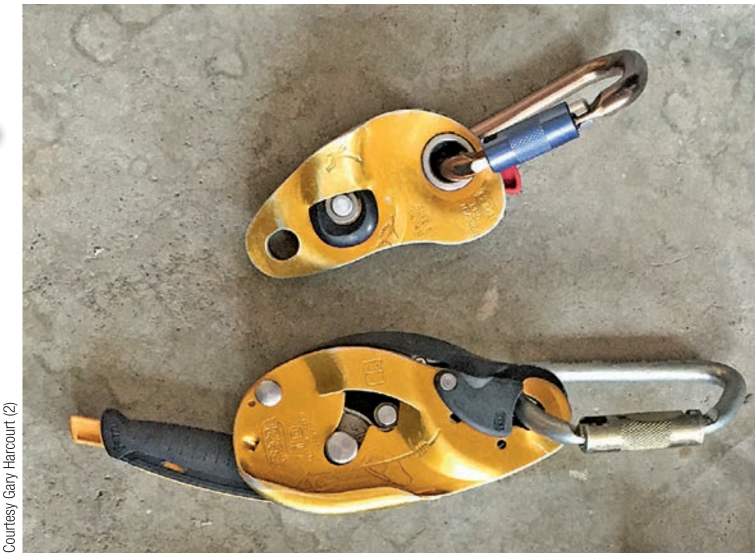
Gary is the founder of Great Rock Windpower, a small-wind service company that installs and maintains a fleet of small wind systems. Gary also is commissioning engineer and installation trainer for Endurance Wind Power, and has climbed and taught across the United States, Canada, the United Kingdom, and Italy. He is a certified tower climbing and rescue instructor who has been training climbers for the past five years.

Gear Picks

Petzl Grillon adjustable work positioning lanyard with Hook connector. This is a versatile, work-positioning lanyard. It can also be used for fall restraint and as a pick-off strap that provides a 2:1 advantage, which is useful for rescues. I like the 2-meter Hook version, but the longer versions work great on lattice towers. They have a loose protective sleeve over the rope and are quick to either hook or wrap almost anywhere. The ease of adjustability allows work up-tower to be quicker, safer, and more comfortable.

Multitools provide a variety of uses—knife, screwdriver, pliers—in one lightweight package.

Courtesy Gary Harcourt (2)



The Petzl I'D can be used for a multitude of things, such as Z-haul and fall-restraint systems, but its main purpose is controlled descent. The I'D Traxion pulley pictured has a one-way stop for hauling heavy items.

Petzl I'D Self-Braking Descender. This device can be used for a descent, a rescue, as a progress capture device, and as a failsafe rescue anchor for rope access backup systems. It is light, compact, and easy to carry. For rope access work, I use three at a time—two large I'Ds are set on anchor straps for two double-length ropes (used as descent and backup lines) and one small I'D for the descent. If the rope worker gets in trouble, a person up-tower needs only to lower the worker using the I'Ds from the top—the rescue is already rigged!

Leatherman Skeletool. How often have you been on a tower and needed a knife, screwdriver, or pliers? My favorite is the Skeletool, with its handy caribiner-type clip. I keep it within easy reach in case of emergency.

Favorite Tower Techniques

- **Pace yourself.** I'm not a senior citizen yet, but I'll admit that if I'm feeling winded while climbing, I often stop and "inspect the tower flanges." It gives you a great reason to take a couple of breaks on the way up and, at the same time, you'll know if the tower you're climbing is in good shape—even if you might not be.

- **Fall restraint.** I use my work-positioning lanyard as fall restraint religiously. I see lots of folks get to their work location or a work platform and rely only on their fall-arrest lanyards. Sure, they're designed to catch you if you fall, but isn't it way better to also have your fall restraint attached so you can't fall? If you're using your hands, you need both a primary and a backup system anyway, so make one of them fall restraint.

- **Use lifelines.** I use a vertical lifeline with a rope grab instead of double-clipping when assembling or inspecting towers when there's no Lad-Saf cable. Only one climber needs to go up to set the backup system. When installing new lattice-towers, you can hook multiple ropes up to the tower before each section gets raised. Then you're free to ascend each leg without a lot of hooking and unhooking at the tower cross members.

Sage Advice

Remain focused on climbing, the planned tasks, and safety. Photographing and phone calling can be extremely useful while up-tower, but can also be a huge distraction that could lead to catastrophe. Refuse to climb with show-offs who don't have a rescue kit or know how to use one. Make it a habit to do a pre-climb check and talk through your safety plans. It will help you stay focused, and it could save you or your climbing partner's life. Keep your connections invulnerable, stay attached, and enjoy the view—it's a great office (most of the time).

Tower-Work Training Options

Airstreams Renewables • air-streams.com

CMC Rescue • cmcrescue.com

Comtrain • comtrainusa.com

ENSA • ensa-northamerica.com

Gravitec • gravitec.com

Lakeside Technical College • gotoltc.edu

Midwest Renewable Energy Association • midwestrenew.org

Miller • millerfallprotection.com

Safety One • safetyoneinc.com

Vertical Safety Solutions • verticalsafetysolutions.com

James Jarvis

James is owner of APRS World, which makes wind turbines for harsh locations, as well as wind-energy instrumentation, and control equipment. James' work frequently takes him to remote helicopter-access sites in Alaska, and to wind farms across the United States. James has been installing and servicing small wind turbines for 15 years, and has been designing and manufacturing them for more than seven years.

Courtesy Anna Jarvis (4)

James Jarvis designs, manufactures, tests, and installs wind turbines in a variety of environments.

Gear Picks

Petzl Pro Vertex Best Professional Helmet (with Petzl Pixa 3 headlamp). My helmet is my No. 1 piece of safety gear. It goes on my head the moment I get to the job site. I like this helmet because it is small for travel, provides full head protection, has straps so it won't blow away, and has an integrated mount for the Pixa 3 headlamp. But it's tight for getting liners and other cold-weather gear to fit under it.

Klein Tools 3239 Adjustable-Head Spud Wrench with a Klein 5417 Leather Holder. I always keep an adjustable spud wrench in a leather holder on my harness. The spud wrench is used to align tower and turbine components, tighten bolts, pry things, or even to hammer stubborn components. It is especially well-suited for tower work because it has a tether hole—a falling spud wrench could be deadly, so I tie off the wrench.

Milwaukee Tools M18 Fuel $3/8$-inch impact wrench. After years of experimenting, I have found the one cordless tool that suits my needs. I used to carry a variety of cordless tools, but when traveling, all that weight is prohibitive. The M18 Fuel has a brushless motor with a lithium battery, and can produce 200 foot-pounds of torque. With a $3/8$-inch square to $1/4$-inch hex adapter, I also can also use normal power screwdriver bits and $1/4$-inch hex-shank drill bits.

Favorite Tower Techniques

- **Have lifelines.** Insist on safety climbs/Lad-Saf. With a permanently installed safety climb, there is no temptation to free-climb the "last little bit." And there is no possibility of selecting an inadequate tie-off point while climbing. It is much faster and less tiring to climb the tower.
- **Take advantage of tech.** Bring a water bottle, snack, and your smartphone. Especially while erecting towers and turbines, since there can be a lot of waiting. The smartphone is great for when you need to download a manual or to document something with a photo.
- **Pack versatility.** Carry a lot of carabiners and small lanyards up the tower. They are infinitely useful to secure parts, tools, etc., to the tower while you work.

Sage Advice

Minimize your work while on the tower. Do as much as you can in your shop or on the ground. Plan your tools and materials so you will have everything you need on the tower.

A good helmet is a vital piece of gear, protecting you up- and down-tower.

An adjustable spud wrench is used for adjusting fasteners and aligning components.

A small impact drill-driver is a versatile, light power tool.

Chris Henderson

Chris works as an engineering consultant on utility-scale wind turbines, co-owns and operates a small vegetable farm in Washington State, and has previously worked as an engineer, regularly climbing meteorological towers and wind turbines, typically 260 feet or higher. He has been trained as a "wind-turbine climber and rescue-competent person" and professionally renews the status every two years.

Gear Picks

Petzl Grillon adjustable work positioning lanyard with Hook connector. This allows me to use both of my hands up-tower, and can be easily adjusted to adapt to my position. This is by far the best positioning lanyard I've ever used—I'm now on my third one after retiring my first two.

DBI-SALA EZ-Stop Elastic Twin Leg Shock Absorbing Lanyard. This fall arrest Y-lanyard allows me to stay tied-off to the tower 100% of the time (which is a golden rule!), has large hooks that fit around most tower legs, and is lighter than older-style all-steel Y-lanyards.

Ropeworks PDQ Personal Rescue Kit. I always have a rescue kit when I climb, and the PDQ is my favorite because, at 9 pounds, it's light enough to bring up-tower. It can be used for a self-rescue/emergency descent, or to lower another climber. The included pulleys provide mechanical advantage to lift an injured climber out of their fall-arrest gear and lower them to the ground.

Chris Henderson looks happy at this height.

Rescue Kit

A rescue kit lets you safely lower yourself or another to the ground in an emergency. It should include a rope, an anchor, a controlled-descent device, several locking carabiners, and a hauling system. The hauling system is a rope with multiple pulleys that can be used to lift a climber who is suspended by their fall-arrest gear. The climber is then attached to the descent rope (which is attached to the tower with the anchor). Their fall-arrest gear can then be disconnected, and they can be lowered to the ground with the controlled-descent device. Climbers can also use the kit to self-rescue and lower themselves to the ground.

All of the equipment should be rated for human rescue—and never used for any other purpose (e.g., lifting operations or rigging). Several commercial rescue kits are available with various safety features and specialized hardware. Training and practice are essential and should be regularly refreshed. There are several options for professional trainings in which you can practice rescuing dummies in a controlled environment—much preferred over having to learn on the job with a coworker.

—Chris Henderson

Ropeworks PDQ Self-Rescue Kit.

Courtesy Sterling Rope

This Y-shaped safety lanyard has two legs for easy repositioning without a break in protection. Shock-absorbing straps reduce the impact of a stopped fall.

Courtesy Chris Henderson (2)

Favorite Tower Techniques

- **Be aware** of your surroundings at all times and take the time to stop working and observe your environment. Weather can change dramatically once you're up-tower, unexpected visitors can show up in the drop zone, or the structure you're climbing may not be as secure as it looked from the ground.

- **Dress appropriately.** Dress so that you're a little too warm on the ground if you'll be working up-tower. The exertion of climbing a few hundred feet will definitely get you warmed up, but the higher you go, the colder and windier it becomes—so plan for it. Take your time going up so you don't get too sweaty, which will quickly make you cold at the top. In cold weather, I often wear a pair of insulated thick leather gloves when climbing, then change to lighter gloves with the tips of the index fingers and thumbs cut off so I can manipulate wires or small parts.

- **Use the restroom before you go up**—there won't be one at the top and your ground crew may not appreciate improvised maneuvers.

web extras

"Choosing a Wind Turbine Tower" by Roy Butler in *HP161* • **homepower.com/161.34**

"Wind-Electric System Maintenance" by Roy Butler & Ian Woofenden in *HP135* • **homepower.com/135.98**

"Learning the Ropes: A Beginner's Guide to Tower Climbing Safety" by Ian Woofenden in *HP128* • **homepower.com/128.66**

"Tools of the Wind-Electric Trade" by Ian Woofenden in *HP124* • **homepower.com/124.98**

"2015 Wind Turbine Buyer's Guide: Why, Where & How to Do Wind Electricity" by Ian Woofenden & Roy Butler in *HP167* • **homepower.com/167.50**

Sage Advice

Realize that when you're climbing, you're engaging in a potentially dangerous activity, so don't be afraid to stop work. If you see something that makes you uncomfortable, stop work and discuss the situation with your crew. Whatever you're working on is not worth a serious accident. When you have the right training, gear, tools, and work plan, tower climbing can be fun and exhilarating.

Comment & Discuss this article @ homepower.com/173.60

AHJs + Requirements vs. Allowances

by Brian Mehalic

This edition of "Code Corner" takes a look at the authority vested in local officials and building departments, the difference between requirements and allowances, and several examples where terminology is critically important to understanding *Code* requirements.

Who Makes the Call?

Section 90.4 in the *National Electrical Code (NEC)* stipulates that the authority having jurisdiction (AHJ) has the "responsibility for making interpretations of the rules, for deciding on the approval of equipment and materials...for granting the special permission contemplated in a number of the rules." In general, AHJs rely on product standards created by national and international organizations and third-party testing to identify that equipment is "recognizable for the specific purpose, function, use, environment, application, and so forth." Additionally, Section 90.7 states that, for listed equipment, "factory-installed internal wiring or the construction of equipment need not be inspected at the time of installation…"

Nationally recognized testing laboratories (NRTLs), such as Underwriters Laboratories (UL), Intertek ETL, TUV USA, and CSA, perform the applicable testing, and "list" manufacturer's equipment to one or more standards, which literally means that the item "is included in a list published by an organization that is acceptable to the AHJ." This inclusion means that the equipment "meets appropriate designated standards or has been tested and found suitable for a specified purpose." If equipment is listed, that typically means it should be "labeled," bearing a symbol or mark from an AHJ-accepted agency indicating adherence to appropriate standards.

Section 690.4(B) requires PV-specific equipment, including combiner boxes, modules, inverters, and charge controllers, to "be listed for the PV application." Other equipment, such as wire, conduit, non-PV specific enclosures, and grounding electrodes, need to be listed for their application, but not specifically for use in PV systems. The AHJ will expect to see an NRTL label on all the gear that makes up the PV system.

Unlike "listed" and "labeled," "marked" and "recognized" are not defined terms in the *NEC*, but are widely used throughout the *NEC*. For example, Section 690.17(A)(1) to (5) details manually operable disconnect types, requiring them to be "marked for use in PV systems." This means that they are listed and labeled to an appropriate standard such as UL98B, "Outline of Investigation for Enclosed and Dead-Front Switches for Use in Photovoltaic Systems."

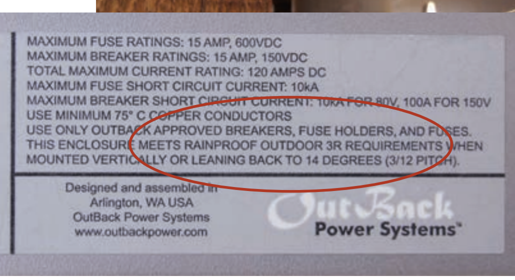
The AHJ truly has the final call—in fact, the *NEC* defines "approved" as "acceptable to the AHJ—and further states in Section 110.2 that the "conductors and equipment required or permitted" in the *NEC* are "acceptable only if approved"! As such, the AHJ can grant "special permission" (Section 90.4) by written consent, so cultivating a good relationship with your local building department, plan reviewers, and inspectors—along with presenting a clear, documented rationale for your request—can go a long way.

AHJs may also be empowered to enforce their own "specialty" codes, or be required to enforce amendments to codes. For example, in North Carolina, the North Carolina Building Code Council adopts and amends the NC State Building Codes, as authorized by state law (General Statute 143-138), and there are several state amendments to the *NEC*; the 2014 Oregon Electrical Specialty Code (OESC) also has numerous amendments to the *NEC*. Or, a jurisdiction can decide to delay adoption of specific sections of the *NEC*, as was the case in Washington and Colorado in regards to Section 690.12 (rapid shutdown) of the *2014 NEC*. Local conditions can also result in requiring specific materials, even when there may be other, listed options. For example, in California's coastal areas or in locations with corrosive soils, local ordinances to modify state Title 24 building standards under limited circumstances may be adopted.

Name That Location

The *NEC* offers numerous definitions to distinguish between the level of moisture a component or enclosure can withstand, and for classifying locations. The following definitions work in conjunction with the NEMA enclosure types in Table 110.28. Of course, the AHJ is free to make interpretations and enforce them.

A piece of equipment is **weatherproof** if it is "constructed or protected so that exposure to the weather will not interfere with successful operation." **Rainproof** means it is tested for successful operation only under certain conditions, including rain, but possibly not for other environmental conditions, "such as snow, ice, dust, or temperature extremes." If these additional conditions are a concern, then weatherproof equipment may be required. NEMA 3R enclosures (which



This NEMA 3R combiner box is rainproof, but not rain- or watertight. The weep hole allows water to drain from the box.

This combiner box has multiple NEMA ratings, including 4X. Note the gasketed cover, which makes it rain/watertight.

Brian Mehalic (3)

generally include residential string inverters) are typically classified as rainproof.

Based on the particular specified testing, **raintight** equipment is "constructed or protected so that exposure to a beating rain will not result in the entrance of water under specified test conditions," while **watertight** equipment is "constructed so that moisture will not enter the enclosure." NEMA 4X enclosures are typically categorized as raintight and/or watertight.

Locations are classified as dry, damp, or wet. **Dry** locations are just that—not normally subject to dampness or wetness (a new building under construction is considered dry, even if it is getting wet inside, since it will be a dry location once construction is complete).

Damp locations are "protected from weather and not subject to saturation with water…but subject to moderate degrees of moisture." Examples of damp locations include "partially protected locations under canopies, marquees, roofed open porches," and can even be indoors, such as some basements and barns. Depending on the AHJ's interpretation, the back of a pole- or ground-mounted PV array could be a damp location. Or these sites may be considered **wet** locations, defined as "unprotected locations exposed to weather," which also include underground conduit runs, concrete pads in contact with the earth, and areas subject to saturation with water.

Required vs. Permitted

Mandatory *Code* requirements are indicated by the use of the terminology **shall** or **shall not.** For example, 690.4(C) requires that PV system equipment and wiring installation "shall be performed only by qualified persons." 690.13(A) mandates that PV system disconnecting means shall not be installed in bathrooms. And Section 705.12(D)(2) requires that 125% of inverter output circuit current—not the rating of the overcurrent protection device—shall be used for busbar or tap-and-feeder conductor calculations for grid-tied systems.

"Shall be permitted" or "shall not be required" is *Code* language for allowances or options. This may apply to authorizing methods that supercede or modify other sections, as in Section 690.7(C), which permits PV source circuits of up to 600 V (maximum system voltage) on one- and two-family dwellings, in juxtaposition to residential voltage limitations in Section 210.6, that states 120/240 VAC as typical. Other examples include: 690.10(C), which allows a single-phase 120 VAC stand-alone PV system to supply power to 120/240 VAC service equipment, provided there are no 240 V loads or multiwire branch circuits; and 690.13(E), which states that a PV disconnect is not required at the PV module or array location. Note that this last allowance may be superseded by the requirement of 690.15(C) that disconnecting means must be integrated or adjacent to combiner boxes mounted on the roof of dwellings or other buildings.

Building or Structure?

The *NEC* definition of **structure** is broad: "that which is built or constructed;" a **building** is defined as a "structure that stands alone or that is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors." This could be a house (a dwelling), garage, office building, factory, or retail space, but not a carport or freestanding gazebo. A building is a structure, but not all structures are buildings.

This matters because Section 690.56 requires a label identifying power sources and indicating the location of the PV system disconnecting means when PV systems are on either a building *or* a structure, thus applying, for example, to both a home or a carport. However, the rapid shutdown requirements of 690.12 apply only to PV systems on buildings—and thus do not apply to a carport or ground-mounted system. The 690.31(G) requirement for DC circuits to be in a metal raceway or type MC applies to circuits inside both buildings and structures. And a big change in the 2014 *NEC* was the removal of "on or penetrating a building" from Section 690.11, effectively extending DC arc-fault protection to all PV systems.

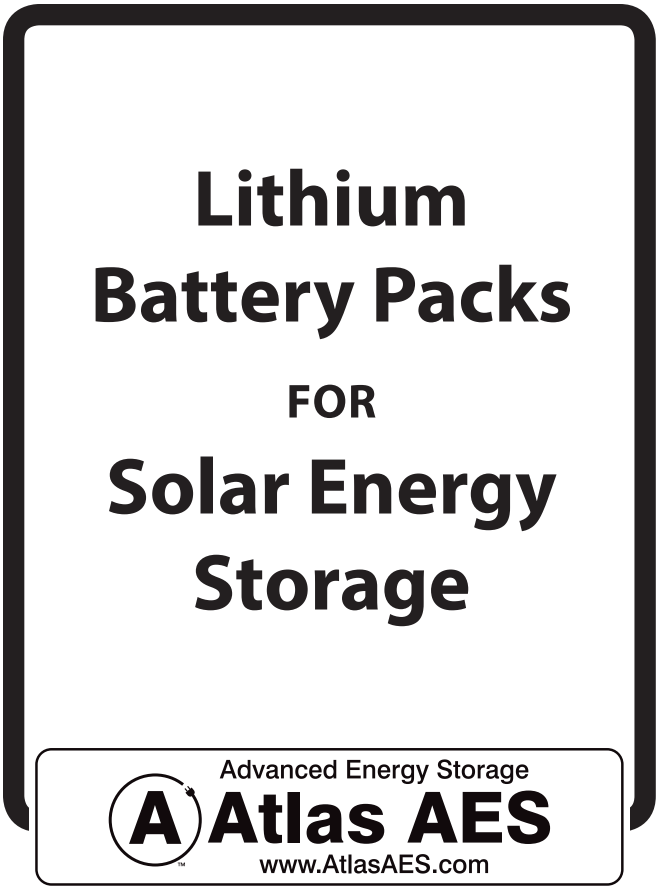
Interconnection Terminology

Per Section 690.4(A), PV systems can supply a "building or other structure in addition to any other electrical supply system." That other supply system is typically the utility grid, and the PV system is interactive and operating in parallel with it—that is, grid-tied.

Note this is not a hybrid system, which the *NEC* defines as "comprised of multiple power sources" that "could include photovoltaic, wind, microhydro generators, engine-driven generators, and others, but do not include electric power production and distribution network systems" (EPDNs, which are "external to and not controlled by an interactive system," aka the grid).

EPDNs distribute power to services at a building or structure. Overhead ("service drop") or underground ("service lateral") conductors are the last leg from the utility distribution network to the "service point," which is the line of demarcation between the utility and the end user. This point of demarcation may be a piece of equipment, such as the meter on a residential service; the service transformer and CT-based metering at a commercial building; or an overhead pole-mounted air-break disconnect switch on a large PV farm. Article 230 covers requirements for services, including disconnecting means, conductors, and overcurrent protection.

Grid-connected PV systems are **power production equipment**, defined as "the generating source, and all distribution equipment associated with it, that generates electricity from a source other than a utility supplied service." Interconnection of PV systems is addressed by Article 705 (see "Code Corner" in *HP162*). However, always consult with the local utility and AHJ to verify their particular service and PV system interconnection requirements.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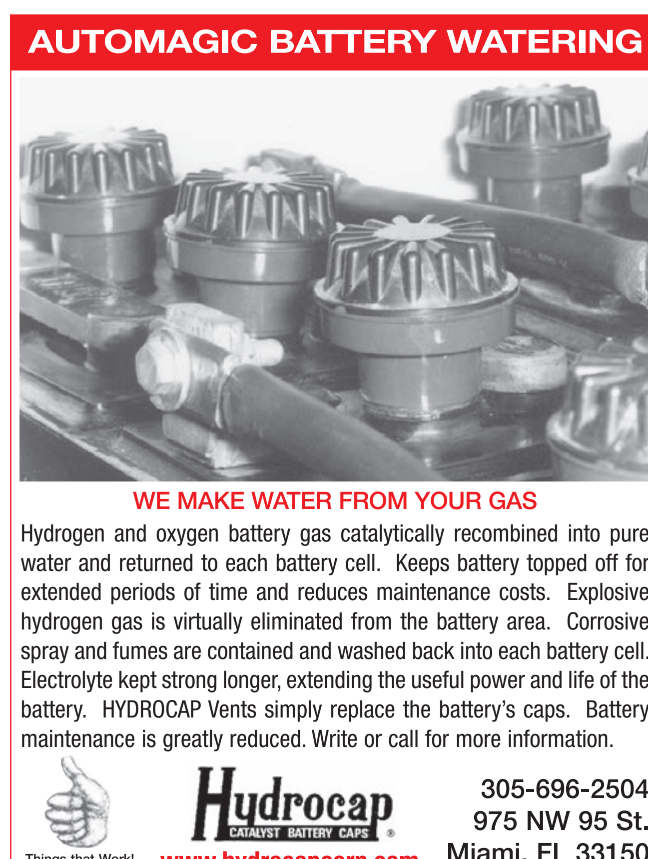
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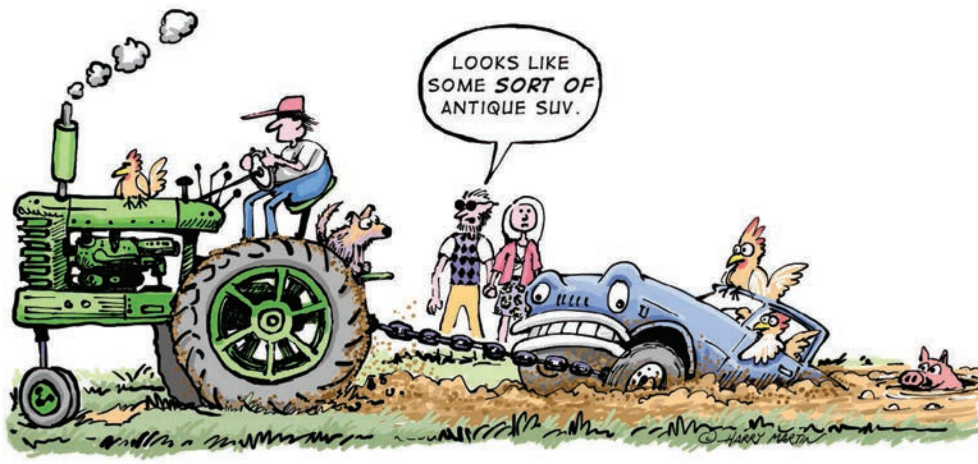
Life Goes On

by Kathleen Jarschke-Schultze

Off-grid living is a constant adventure. At least it is for my husband Bob-O and me. Even though our lives fall into a pattern of seasonal-oriented tasks, we can count on the unexpected occurrences to enliven our existence. Sometimes it is a good thing and sometimes it is a good story—when it is over.



Harry Martin

On the Road Again

Our homestead is 1.8 miles from the main road, where our mailbox is located. Our route up the creek is an ever-morphing dirt/rock road. For the last 25 years, Bob-O has been the road maintenance crew. He's the only one with the heavy equipment needed to repair our access to the outer world.

Not only does Bob-O use his tractors and backhoe to repair the road, we are the ones who have been buying the gravel. Gravel can be cheap, but getting it transported can cost four times the price of the gravel itself.

In the last few years, we have been acquiring neighbors. There were three homes in our neighborhood when we moved here—now there are eight that I know of.

As the neighborhood populated, I put up gentle reminders in an attempt to preserve the road: "20 mph: dry road; 10 mph: wet road." I decorated the signs with pictures of little flowers or raindrops. Some people actually complied, while others ignored or even ramped up their speed. (I have two more signs in mind: "Drive Fast and the Road Won't Last" and "Up the Creek You Go, Drive Slow.")

So I put up a sign that read, "Want This Road Fixed? $$/Labor" with our phone number underneath. That way, if people did not have money, they could contribute with labor. One neighbor did call and offered his labor. That was a couple of years ago.

Rocky Road

One of our new neighbors has a small quarry on his property and has given us permission to quarry road gravel there. Bob-O has a dump trailer and the quarry is close enough to drive the backhoe to. Right now, our road is sporting some newly filled potholes along with some built-up stretches, but it was like the old river-crossing puzzle; the fox, the chicken, and the grain; to get all the equipment in the right place at the right time. Luckily, that same guy and another neighbor came to help Bob-O two days in a row. With the backhoe at the quarry, the tractor down on the road, and the truck and dump trailer going between the two, they got a lot of work done.

This past January, a flash flood washed out a section of road almost down to the culvert pipe. Repairing it took a lot of work. Bob-O says the problem with working on the road is that when you fix the worst places, they become the best places and then you notice how bad the other problem areas are.

Mud Warriors

Just before Christmas, Bob-O and I went to town to see *The Force Awakens.* (Bob-O says I have the "science affliction.") It was after dark by the time we came home. As we neared our turnoff onto the creek road, we saw two flashlights being waved frantically up ahead. Of course, we both said, "Oh, s**t" at the same time. We immediately thought, "Road accident!" It's been 26 years since we trained as emergency medical technician first responders. The ABCs—airway, breathing, circulation—ran through my brain. Bob-O stopped the car and rolled down the window as the lights rapidly bobbed toward us. A young couple ran up and asked if we knew where they could get cell phone reception—once you drop into our canyon, cell service is bad to non-existent. On their way to a grandmother's house in Los Angeles, they found the campground at the start of our road and planned to pitch a tent there overnight. But they drove off the main road and right into rain-soaked adobe clay. The pickup, already low on clearance, was in the muck up to the bottom of its doors.

Room at the Inn

Bob-O said, "Get in, and come spend the night at our house. If you need to call someone, we have cell service at the house.

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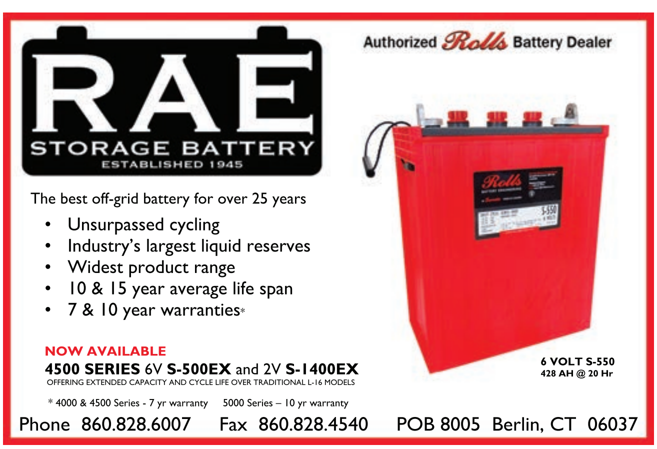
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You can't do anything tonight and I can pull you out in the morning." They piled into the back seat with Lucea, our Airedale. Once back at the house, we could see they were young city kids. I fixed them some dinner as they had eaten only trail mix all day. We talked for about an hour then we all hit the sack. I'm glad I always keep the guest room ready.

Muddy Roads

In the morning, after coffee, eggs, and jalapeño cheese bagels, Bob-O jump-started the diesel pickup (we hadn't driven it in so long), loaded up chains and such, and drove back to the campground. I followed in my car with the dog. As he carefully approached their truck from the opposite direction, his truck got stuck. I drove him back to the house and he got one of the tractors.

I followed him back down the creek. We first chained up his truck and towed it back onto fairly good ground. He brought the heavy metal forks that attach to the tractor's front bucket, using them to raise the truck up out of the mud enough for the guy to crawl underneath and carefully wrap the chain around the rear spring shackles (there was no tow point on their pickup!). After lowering the truck back down, Bob-O turned the tractor around and hooked on. It was so very slow going as the little truck was literally pulled through the mud. The bottom third of the tires did not appear until the truck came up onto the roadbed proper.

The rear tractor tires, with their huge tread, churned slowly in the clay abyss, but inch by inch, the tractor kept moving. We cleaned the tires and our boots off as much as we could with a shovel. We hugged, exchanged info, they gave us some Seattle coffee (in the bean, the way we like it). Then, over the hills and through the woods to grandmother's house they went.

Up the Creek

Land up the creek is getting more populated every year. One reason is that the cheapest land is still beyond the grid. But we have seen neighbors come and go. The rural off-grid life is a remote, hands-on lifestyle—the idea of that is seductive, but the reality is not for everyone. We've witnessed people move here, only to crumple under the everyday toil and leave within a year. Some have lasted longer, only to fold their cards and go after years of creek life. Isolation, transportation, employment, school, phone, and Internet access are a few of the hurdles. Those, thrown in with being your own plumber, power utility, road maintenance crew, and HVAC and water utility can be insurmountable challenges for some.

We have some neighbors who have been able to adapt and put down roots. Others are still in the barefoot stage of off-grid growth. After 25 years, we've found that, whether neighbors or strangers, many can be counted on to provide assistance, amusement, and adventure.

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Understanding Wind Speed

Two completely different wind speed measurements are commonly used when talking about wind energy systems: **instantaneous wind speed** and **annual average wind speed.** If we mix these up, we will misunderstand wind site assessment, wind turbine ratings, and projections of wind energy available on your site.

Instantaneous wind speed is an immediate, real-time measurement of what the wind is doing—the "right now" wind speed. Today's measuring equipment may record it every second or even more often, and we can watch the results on a digital or analog monitor. What you'll probably notice first while observing an instantaneous wind speed readout is that it varies a lot and quickly. The wind speed can bounce around from a few miles per hour to tens of miles per hour in a matter of seconds.

Instantaneous measurements can help determine the maximum (peak) wind speed at your site over a certain time period—an indication of how severe a site is, and therefore how durable the turbine needs to be. Wind turbine designers use instantaneous wind speeds when looking at governing (overspeed protection) and other controls. And power curves correlate with instantaneous wind speeds, predicting the instantaneous power output at given instantaneous wind speeds (see the power curve article in *HP127*.) For the end user, instantaneous wind speed measurements are not very useful, and can be distracting.

Instantaneous wind speed measurements range from zero to more than 200 miles per hour at extremely severe sites on mountaintops and at sea. Typical residential wind sites might see 80+ miles per hour, once or several times a year.

The **annual average wind speed (AAWS)** is the primary wind measurement needed, as an average of all the wind experienced at a site, for all seasons of the year. This measurement normally encompasses many years of data.

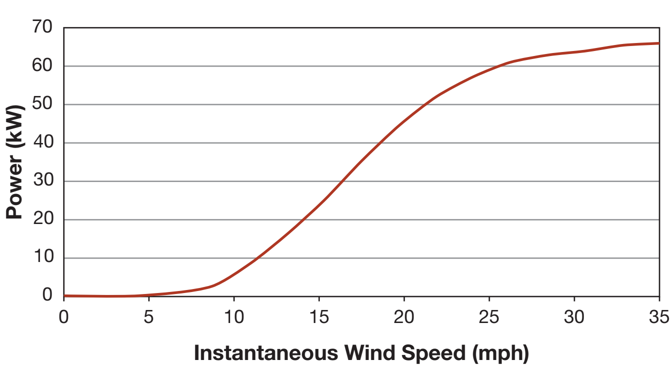
We are primarily interested in energy (watt-hours), not power (watts; instantaneous rate of generation). Energy is a result of the average wind speed on a site; power correlates with instantaneous wind speeds. Because wind speed varies significantly over any time period, you can expect the power and, therefore, energy, to vary as well.

But it's even more complex than this, because wind power is a *cubic* resource. If we double the wind speed, the available power increases eight times. An annual average wind speed takes this into account (using a standardized "wind distribution"), and gives us a measure of wind energy that is reasonably accurate and reflects the total energy available from a variable resource. Typical residential wind energy sites may have annual average wind speeds of 7 to 14 mph, with the high end being quite a windy site. Utility-scale wind sites start in the 12 to 14 mph range; the best sites may approach or exceed 20 mph annual average.

Keeping these two wind measurements—instantaneous and annual average—clear and distinct will help you make sensible analysis of wind sites and wind turbines. Focus on the annual average wind speed (and kWh generated in that wind regime), and don't worry too much about instantaneous wind speeds, except to be aware of the peaks.

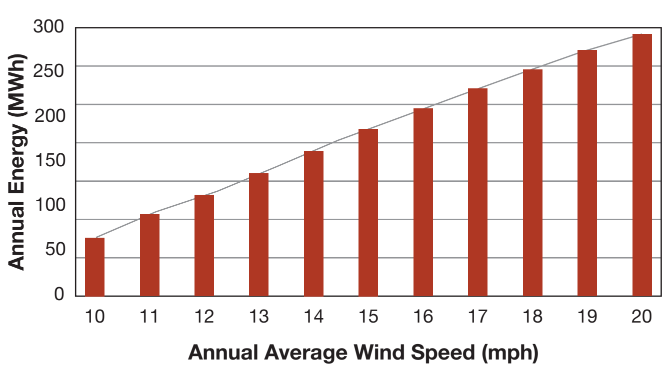
—Ian Woofenden

Instantaneous Wind Speed



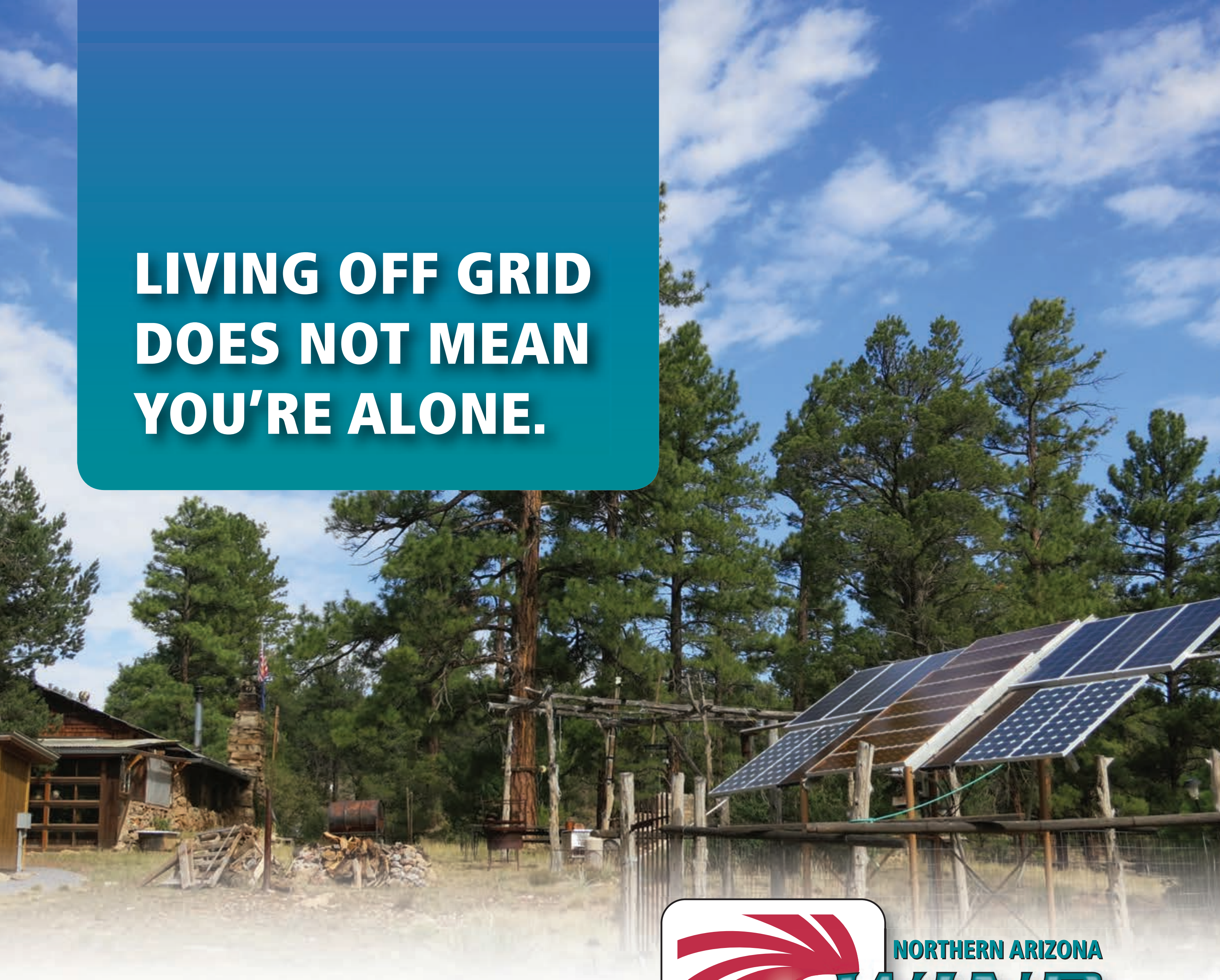
Instantaneous wind speed measurements and power outputs are not useful data except for turbine durability purposes.

Annual Average Wind Speed



Annual average wind speeds and energy (MWh or kWh) data are the important numbers to focus on.

Note: The graphs shown are examples only, and not representative of one machine or general conditions. Each wind turbine has its own power and energy numbers.



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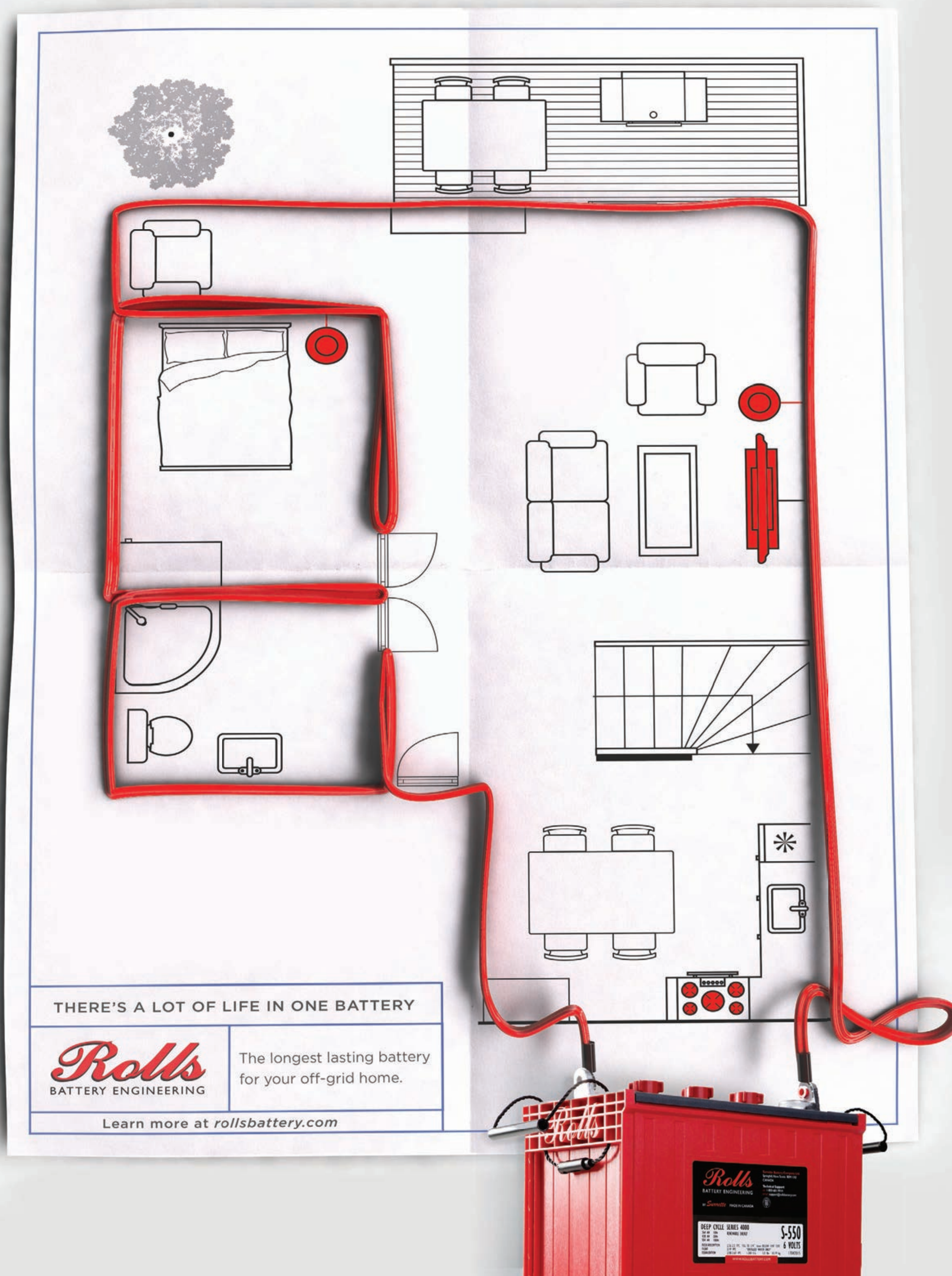
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