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Nov. & Dec. 2018, Issue 188

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All Good Things In All Good Time

Ian Woofenden

The often boisterous post-dinner crew conversations that took place around the table at *Home Power* founders Karen and Richard Perez's off-grid homestead could run for hours. On any given evening, the talk could range from the esoteric ("Should we tweak the float voltage of the Heliotrope two-tenths of a volt for the winter?") to lofty pondering ("What would happen if PV hit a buck a watt?"). What "mainstream" solar might look like was well-tread ground, as was one of Richard's only partially tongue-in-cheek regular musings: '"If we do our job well, solar will become so common, so ubiquitous, that we'll put ourselves out of business."

This edition of *Home Power* (November/December 2018) marks the end of the magazine's 31-year, 188-issue publishing run. It's likely no surprise that publishers of all sizes, and especially small, independent ones like *Home Power,* face a challenging business landscape. The importance of quality content can get lost as businesses chase metrics measured in clicks and likes, and readers are less inclined to pay for content. Ironically, and in tune with Richard's thoughts, the solar industry's success has made *Home Power*'s highly technical content more appropriate for niche enthusiasts.

In 1987, Richard and Karen began publishing *Home Power* with the mission of changing the way people generate energy, one rooftop at a time. Their vision was truly revolutionary. The couple passed their skills and responsibilities to the rest of us in 2001. During these 17 years, the *Home Power* crew has continued the push to make solar mainstream. We are extremely proud of the current state of the solar industry and our decades-long role in its evolution and growth. We're also very grateful for our dedicated readership, which has allowed *Home Power* to advocate for renewable energy for more than three decades.

Actions that originate from people, organizations, and movements occur at a given place and time. The action itself may be a quick flash of an idea or a sustained effort that crosses decades. Thirty-one years ago, *Home Power* was a glimmer of an idea that would morph into a committed endeavor to help demonstrate how clean, green power can change people's lives. As long as the sun shines, this effort will continue to radiate, long into the future.

—Joe Schwartz & Michael Welch,
for the *Home Power* crew

Note: Current Home Power *subscribers can donate the value of their remaining issues to offset the magazine's remaining operational expenses. If you'd prefer a refund for the value of the remaining issues of your paid subscription, please email* refund@homepower.com. *Call 800-707-6585 if you don't have access to email.* Home Power *will continue to host digital editions of its archive online.*

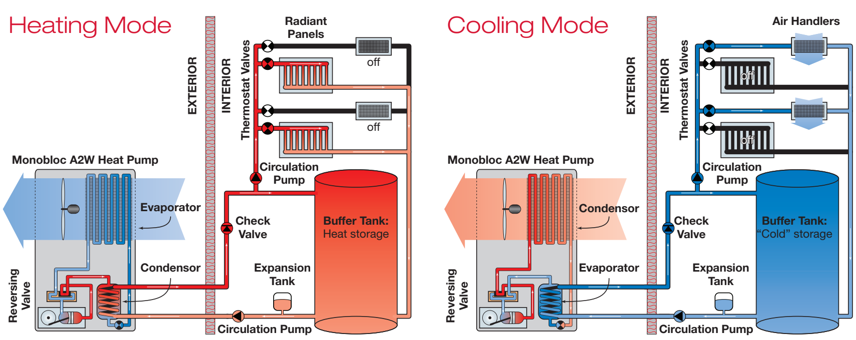
Think About It...

"We're all [solar] bozos on this bus."

—The Firesign Theater, as co-opted by Richard Perez

Main Features

continued on page 6



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On the Cover

The complete collection—188 *Home Power* magazine covers, spanning 31 years. Over three decades, we've featured solar-, wind- and hydro-powered homes, homesteads, and businesses; cars, buses, boats, and planes; and many motivated, caring, and committed human beings, plus even a few dogs. Thanks, everyone, for making this all happen!

Photos: Various Artists

Photos courtesy We Care Solar; Powerley

MIDNITE INVERTERS

MidNite inverter systems are game changing innovations that will revolutionize system design and installation.

THE MNB17-5 AND MNB17-3

The MNB17 is the most advanced battery based inverter/charger system ever devised. The MNB17 inverter/charger and MPPT solar and wind modules are hot swappable and available in various voltage configurations. There are two models, the MNB17-5 and MNB17-3. The MNB17-5 has up to five 2kW inverter/charger modules, up to two 5000 and 8000 watt MPPT modules depending on the model. The MNB17-3 is primarily the same unit as the MNB17-5 with 3 module bays.

THE BARCELONA

The Barcelona, a 130 amp 48V output/600V input MPPT Solar charger with two independent PV inputs. Options include arc fault, ground fault and rapid shutdown transmitter. Canbus communications is standard.

THE ROSIE

The Rosie Inverter/Charger is a 2800 watt,12V and 5000 watt 48V volt inverter for mobile and renewable energy off-grid applications. The Rosie electronics compartment is sealed from outside air. Control is via the MNGP2 built into the Barcelona or as a separate stand alone display.

The Rosie

The Barcelona

MNB17-5

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Up Front

Photos courtesy AP Systems; S-5!; solarabcs.org

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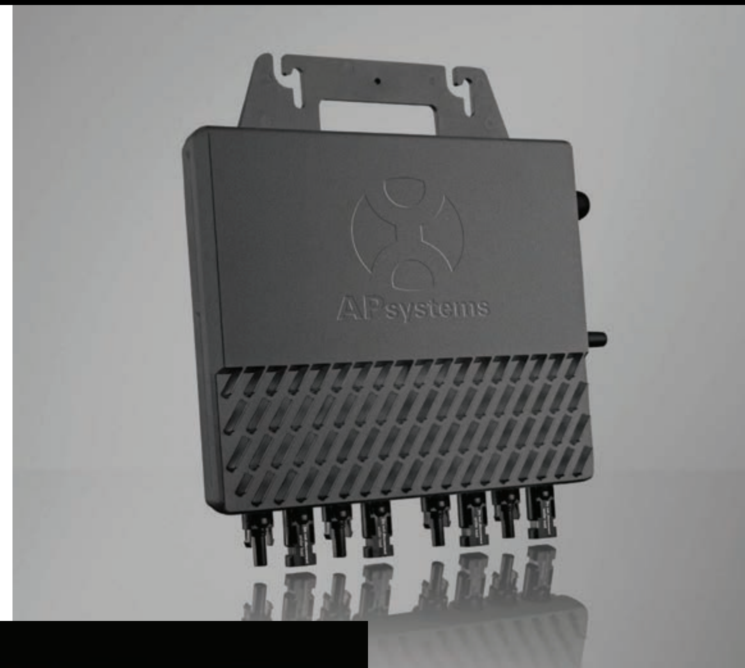

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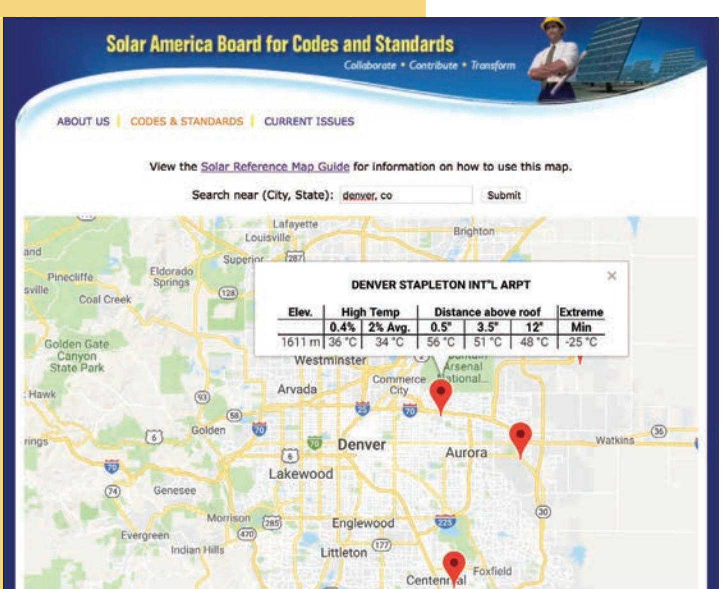

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In Back

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Back Issues

Interested in past *Home Power* content? We'll be opening up our 31-year digital back issue archive for free download access via homepower.com in early 2019.

Individual hard-copy *Home Power* back issues are not available for purchase at this time.

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PO Box 520 • Ashland, Oregon 97520 • USA

contributors

this issue's experts

Since 2006, **Ted Dillard** has been converting gas motorcycles to electric and writing for *InsideEVs, Home Power,* and evmc2.com. Ted's book, *Power in Flux: The History of Electric Motorcycles*, is about research, innovation, and the confluence of two-wheeled technologies.

Monali Mujumdar conducts research in lighting and other technology areas. She previously worked for ABB India in its Medium Voltage Switchgear Division, where her focus was designing protection systems for heavy machinery. Monali has a doctorate in electrical engineering from the University of Wyoming.

John Siegenthaler is a mechanical engineering graduate of Rensselaer Polytechnic Institute, a licensed professional engineer, and professor emeritus of Engineering Technology at Mohawk Valley Community College. "Siggy" has more than 40 years of experience designing modern hydronic heating 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.

Benjamin Root has more than 20 years on-staff with *Home Power* as art director. Mixing artistic inspiration with technical nerdism, Ben especially loves dispelling the myths and misconceptions of renewable energy. He approaches graphic design from the eyes of an educator, with the intent of helping everyone become successful and satisfied renewable energy users.

Michael Welch, a *Home Power* senior editor, is a renewable energy devotee who would have celebrated his 29th year of involvement with the magazine in 2019. 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.

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

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

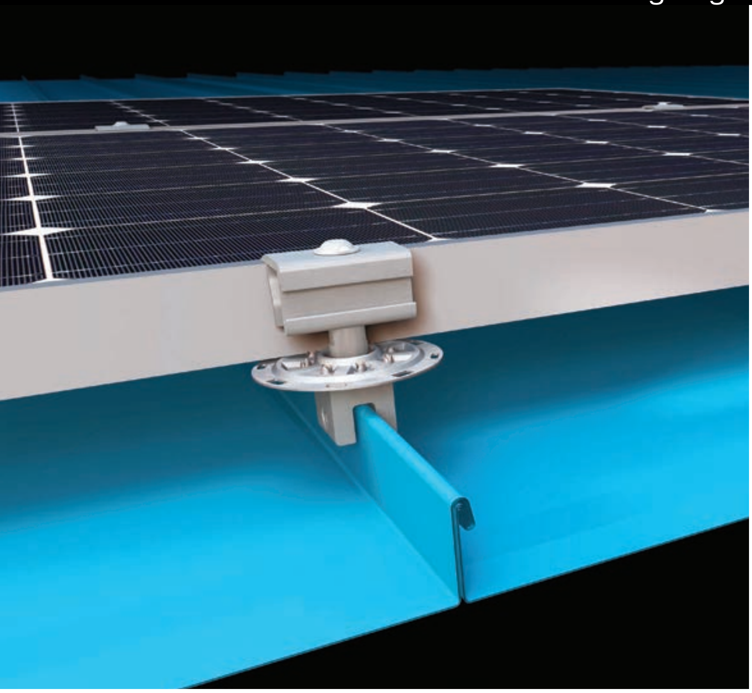
Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people-power technologies. In addition to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching,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

Ryan Mayfield is the principal at Mayfield Renewables, a design, consulting, and educational firm in Corvallis, Oregon, with a focus on PV systems. He also teaches online courses in conjunction with *SolarPro.*

Joe Schwartz is publisher of *Home Power* and *SolarPro*. He attended Solar Energy International in 1995 and worked as a PV, wind, and hydro systems integrator prior to entering technical publishing. Joe lives off-grid, and holds a Limited Renewable Energy Technician license in Oregon.

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.

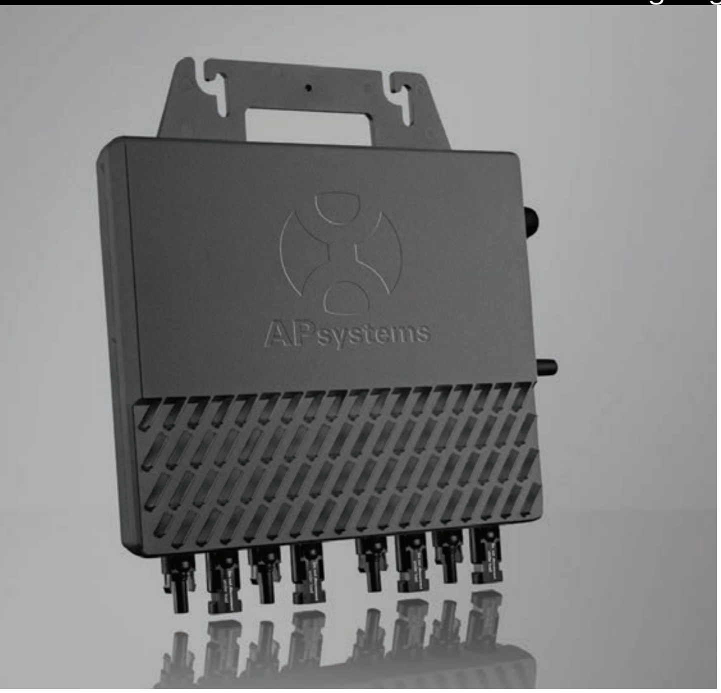


Courtesy S-5!

S-5! PV Kit 2.0

S-5! (s-5.com) released a new PV Kit for nonpenetrating flush-mounting on standing-seam metal roofs. This UL 2703-listed system does not require rails and accommodates module-frame thicknesses between 1.29 and 1.81 inches. Kits include the PV Disk, which supports the module frames with bonding teeth for integrated grounding; a module-placement bevel guide; and wire-management tie-off holes. MidGrab and EdgeGrab standoffs come preassembled with low-profile bolts that attach to standing-seam clamps (such as the S-5! clamp; sold separately). The MidGrab standoffs provide a 1-inch gap between modules. Kit components are also available in black.

—Justine Sanchez



Courtesy AP Systems

AP Systems

QS1 Four-Module Microinverter

AP Systems (APsystems.com) introduced a four-module, 1.2 kW microinverter with independent MPPT for each PV module. This product is intended to save installation time over other module level power electronics (MLPEs), in which each module is connected to a separate MLPE. Each DC input can handle up to a 375 watt module; each output is rated up to 300 W. Operating voltage range spans 16 to 55 VDC (MPPT range, 22 to 48 VDC), to accommodate 60- and 72-cell modules.

—Justine Sanchez

Off-Grid & Lovin' It

My new Zero DSR electric motorcycle is charged by solar, and has yet to connect to the utility grid. With its 14.4 kWh lithium-ion battery, the DSR has a range of up to 205 miles on a single charge. I am getting 140 miles per charge ascending and descending 2,500 feet of elevation on a typical trip. The DSR accelerates faster than any fueled production motorcycle: 0 to 60 mph in 2.5 seconds. While the DSR is electronically limited to 100 mph, "there's an app for that" meaning that a dozen performance and economy settings of the bike, such as torque, maximum speed, battery regeneration when braking, etc, can be tuned.

I have been a *Home Power* subscriber since 1999, when I moved to my off-grid home in the Santa Cruz Mountains, the home of Zero motorcycles. My old Trace inverters are still operating (the darn things won't break so I haven't needed to replace) with almost 4 kW of PV modules. The Siemens VersiCharger US2 Level 2 charger allows selective power draw to match my PV array's output. At 100% (6.6 kW), it charges the DSR in two hours. I have it "detuned" to 25% output until I increase my solar array.

All 30 of the homes in my subdivision are off-grid. There are no utility poles here. Far from being in the boondocks, the community is only six miles as the crow flies from Silicon Valley. Only DC generators were available when the land was subdivided in 1972 and the first homes had 12 V cigarette-lighter sockets in every room! Now, each home is powered by solar electricity with some wind, batteries, and backup generators. Microwave-based Internet started by a neighbor on the ridge having line-of-sight to each home and line-of-sight to a Silicon Valley ISP became available in the 2000s.

Many of my neighbors have electric vehicles—Ford Energi, Chevy Bolt, Nissan Leaf, Toyota RAV4 EV. One surprise of getting into EVs is the availability of cheap or free public charging stations. The local county parks, universities, and community colleges provide chargers, sometimes for free. When there is a fee, it is there as a "parking fee." Many charge with solar power generated on-site.

I'm loving living off-grid within spitting distance of 4 million Bay Area people who don't!

Mark Haynie • La Honda, California

Solar Sundial

As much fun as it is to focus on kilowatt-hours and therms and such, I'd like to remind you of an original solar app that still works amazingly well—a large vertical sundial. It is a great addition to any wall with good solar exposure, and can be as beautiful as it is accurate, limited only by your creativity.

I'm just finishing a vertical sundial inspired by the dramatic old dials scattered around Europe. Covering one side of my garage, this dial is large enough to tell both time and date with good precision. The hour lines are pretty typical for such a sundial, but the artistic presentation is where the fun lies. I chose my home state of New Mexico as the theme, embedding details at key dates and times across the dial. Birthdays, anniversaries, and other notable events can be memorialized at their appropriate places.

With just a little planning, you can create your own personalized dial near where you spend your days. Start by making and mounting a certain triangle—known as the gnomon—up out of harm's way. After that, over a six-month period, you'll need to mark the position of its shadow at precise times on a few dates. A timer on a cell phone works perfectly for

Courtesy Mark Haynie (2)

The Zero DSR electric motorcycle goes from 0 to 60 mph in 2.5 seconds. Its 14.4 kWh battery can provide up to 205 miles of range.

Mark Haynie, shown with several modules in the 4 kW PV array that provides electricity for his home and transportation.

Courtesy Jay Campbell

Jay Campbell's vertical-design sundial is beautiful and functional. Learn how to make your own on his website: newmexicosundial.com.

that, and gets you outside every half hour. Once the lines are set, the artistic fun begins!

I have posted more complete instructions and a lot of background information on my website, newmexicosundial.com. Take a break from your power meters and get in touch with a direct-solar application. You'll come to appreciate medieval science a little, and will certainly learn more about solar tracking. May a thousand sundials bloom!

Jay Campbell • via email

Another EV

I was surprised that the recent article on electric cars did not mention the electric Kia Soul. I have been driving my EV Kia for a year and a half, and wouldn't trade it for any of the electric cars mentioned in the article. It has a more upright driving position than virtually all of the others, which means easy in and out, greater visibility, and more space inside. And if I don't use many accessories, it offers up to 124 miles of range (more range than the BMW i3). If I buy out my lease, my Kia will cost me about $23,000 (also much less than the BMW i3), not counting the tax benefits. And my dealer has these cars available.

Mac Zirges • Newport, Oregon

Imagine Peace & PV

As *Home Power* magazine's 31-year run comes to an end, it's worth considering where we've come from—and where we are heading. Each of our stories are different, while we've all benefited from the improved technology, lower costs, and higher levels of awareness and education over the years.

I moved off-grid in 1980, and had only a few helpers to support me in my off-grid journey. Windy Dankoff (who started writing for *Home Power* in *HP2*) was my main guru, helping me with advice, equipment, and encouragement. In 1987, something quite remarkable happened—*HP1* landed in my mailbox, with no advance warning. It was shockingly wonderful to be connected to others who were living the renewable energy dream, and have more suppliers, advisors, and renewable friends to connect with. *Home Power* became the go-to source for renewable energy information and helped kick-start an industry.

In 1998, I joined the *Home Power* staff, working first on *HP67.* Twenty years and 120 issues later, the industry and the reality of renewable energy look very different.

I bought my first PV modules in 1984 for more than $7 a watt—and that was for the modules alone. Today, I can buy a professionally installed system for half of that, including all of the equipment and its installation. When I started with renewable energy, virtually all systems were off-grid. Today, most new systems are on-grid, use the grid for backup, and support a more diversified and resilient grid.

When I started hosting project-based workshops in the mid-1990s, it was a challenge to get my environmentally oriented friends to pull out their wallets and invest in clean energy for their homes. The general public was not only unwilling, but many didn't even know or believe that solar energy worked. Today, there's a general acceptance about the functionality of renewable technologies. Many people have seen RE systems in

Courtesy Mac Zirges

Mac Zirges appreciates his electric Kia Soul crossover SUV.

operation at their friends' homes, in their neighborhoods, or at local businesses. We can fight about the politics and we can make excuses about why we are still using lots of dirty energy, but most people know that using clean natural resources is the right thing to do.

Today, my clients don't spend a lot of time discussing the pros and cons of renewables versus fossil fuels. We talk about energy efficiency, about system sizing, about the financial investment and return, and about system configuration options. Underneath these discussions, there's a general desire to have cleaner energy systems that are more local, more robust and reliable, and systems that take advantage of the "free fuel deliveries daily" (a bumper sticker slogan from the early days of the RE movement) that we are blessed with.

Some of my neighbors painted a strong political statement on the roof of their house, speaking to the loud, expensive, and violent fighter jets that too often spoil the serenity of our little island. Next door, clients of mine made another large rooftop statement by powering their large and modern home completely with PV. Both families are trying to move toward a better world by speaking about and acting on their values.

Ian Woofenden

As *Home Power* steps off the publishing stage, we leave behind a long history of promoting peaceful clean energy. I'm grateful for all my coworkers at the magazine over the years, the hundreds of authors and other contributors, and to all of the readers who supported the mission by subscribing, reading, sharing the information, and taking action in their own lives. May the progress continue, and may we work toward more peace and more renewable energy.

Ian Woofenden • *Home Power* senior editor

Smoke & Solar

The summer of 2018 was a bad year for wildfires in the West. Where I live in southern Oregon, we had about six weeks of continuous wildfire smoke from nearby and even not-so-nearby fires. Sometimes, the smoke was so thick that the sun looked like a matte orange rubber ball in the dark gray sky; during those times, air quality here was reported to be the worst in the world.

My estimates are that my PV system's production was reduced 15% to 30% during those smoky days; smoke, like clouds, prevents sunlight getting to the PV array. This is a rough estimate, since I've only had the array for two summers—and we had some smoke last summer, too. Peak sun-hours in June sometimes reach 40 kWh. In August during the fire season, we had just over 20 kWh. A 30% loss may be conservative.

Besides the smoke itself blocking out the sun, it left particulate matter on the array (and cars, and pool toys, and plants). Little ashy-dust particles covered everything and turned into a sticky, brown, sweet-smelling film if it got damp. For sure, this too affected my PV system's production.

Benjamin Root

The two lower rows of modules (one subarray) have been washed; the upper two rows are still covered in ash and dust. The difference in production was nearly 8%.

On September 1, when the smoke had cleared, I compared the output of my two identical series strings. At 4:33 p.m., they were producing 1,317 and 1,313 W, respectively—a 0.3% difference. I gave the bottom subarray a good washing. The next day, near noon, I again compared the two subarrays. The still-dirty string was producing 2,056 W, but the freshly cleaned string was now producing 2,232 W—almost an 8% difference.

Assuming that the performance reduction from the ash buildup increased over those weeks, we can speculate that dirty modules were ultimately contributing 25% to 50% of the losses. To be fair, we often don't receive any rain in the summer. Plus, we're located near farms, so dust buildup is typical. But as wildfire smoke and ash become more typical, here's a reminder to wash your array. It's more important than washing your car!

Benjamin Root • *Home Power* art director

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EnerSys
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Affordable Electric Bikes

I'd like to ditch my car and use a bike for most of my local errands. However, the area I live in is hilly and I'd be ferrying my 6-year-old (and groceries) in a trailer, so I need some assistance while I build up my endurance. I don't have a big budget ($1,500 max). Is there a reliable, durable electric bike that will be able to provide enough assist for me to tackle the hills with a tot in tow? What are your recommendations?

Sage Anders • Lopez Island, Washington

There's a lot to choose from in the electric bike market, but most of them are a little more expensive. The Blix Aveny, for example, is a top-rated, classic step-through styled bike with motor rated at 350 watts, with a twist-on-demand throttle. It sells for $1,899. Rad Power Bikes has a line of 750 W bikes in the $1,700 range.

We'd recommend at least a 500-watt motor for the load you're pulling, and you need to consider whether you would prefer a standard throttle control, or a "pedal assist" or "ped-elec" system, which increases the power from the motor proportionally to the force of your pedaling. With the throttle, you simply apply more power as you want it, whereas the pedal assist automatically adjusts the amount of power for you, which, of course, you can adjust by exerting more of your muscles on the pedals. The pedal-assist is by far the most common type today, and some bikes work both ways.

If you're handy with tools, you might also consider adapting your own bike, which is less expensive than buying a ready-made electric bike. You can use nearly any bike, installation is relatively simple and requires basic bicycle tools. See our "Electrify Your Ride" article, homepower.com/146.84

The advantage of adapting your own bike is that you can get a more powerful system for less money, and tailor it to your specific needs. Oh, and building it can be fun!

Your local bike shop may be able to help you. Many stock e-bikes, and often they're major brands. A few will do conversions and custom-builds for you as well. I highly recommend taking a few test rides to see what you like.

Finally, still close to the price range you mention, are some of the "cargo" electric bikes like Rad Power Bikes' RadWagon, a 750-watt workhorse ($1,799). Good luck, and happy riding!

Ted Dillard • EV expert

Improving a PV System's Performance

My PV modules are installed at a 10° tilt here in the Applegate Valley in southern Oregon. I know this is a much lower angle than is optimal. I am wondering if either flat or parabolic mirrors mounted at a downward angle at the top end of the array would improve its performance. If so, do you have any suggestions as to where I would obtain appropriate mirrors?

Walter Lindley • via email

My array is also mounted at a 10° tilt, and I'm near Talent, Oregon. When I ran my specs through NREL's PVWatts Calculator (pvwatts.nrel.gov), the estimated loss (compared to an "ideal" annual tilt of 32°) was about 6%. This is based on a batteryless grid-tied system that can take full advantage of our long, sunny summer days. (See "Sun & Shade with a Double-Duty PV Pergola" in *HP182* for a full description of my system.)

Courtesy Rad Power Bikes

Rad Power Bikes' RadWagon is one of many electric cargo bikes now on the market.

Benjamin Root

In its first full year of operation, my system has produced more kilowatt-hours than projected by PVWatts. That could be due to many factors, including microvariables and defaults in the PVWatts parameters; additional production from my bifacial modules; or the possibility that we had more sun-hours last year than average.

If you have a battery-based system, tilt matters more, since you'll likely need good winter production. You could compare the cost and complexity of adjustable-tilt racks with the cost of increasing your PV capacity by expanding your system with more modules. Be aware that past attempts at focusing insolation onto PV tended to drive up the cell temperature, thus decreasing efficiency. Some concentrating PV modules even burned their cells to the point of damage. Focusing requires dual-axis tracking, which keeps the focal point on the cell; even simple reflectors would be pointing the wrong way for most of the day. This scheme is perhaps more trouble than it's worth. And even simple mirrors may void the warranty on your PV modules. Adding PV capacity to your system would be much more straightforward and eliminate the risk of damaging your modules.

Ben Root • Art director, *Home Power* magazine

PV System Efficiency & Roof Planes

I have a gable-style roof, with roof planes that face due east and due west. I'd like to install a grid-tied PV system that produces electricity at its maximum efficiency. For best performance, should I put an equal number of solar-electric modules on both sides of my roof or favor one side over the other?

James Thunell • via email

PV arrays provide their best efficiency when aimed directly at the sun. When their horizontal or vertical angle to the sun is not straight on, reflection losses increase, and the number of photons hitting the surface decreases. The sun's horizontal and vertical positions change throughout the day and vary during the year. The sun's brightness (irradiance) is lower in the morning and evening. However, small deviations in the angle of incidence result in only small efficiency losses.

Maximum power point tracking (MPPT) helps maximize a PV array's production by electronically determining and adjusting the best balance between voltage and amperage of both the PV array and the battery bank (or utility grid). The efficiency gains of MPPT help offset the losses from a poor angle of incidence.

Your utility may benefit most by production from PV arrays that face east and west, and you may benefit as well. Their load demands are highest in morning and evening, which matches the production peaks of east- and west-facing arrays. In contrast, a south-facing PV array's production peaks near noon, when the utility doesn't need as much incoming energy. If your utility uses time-of-use (TOU) billing, your electricity rate per kWh consumed can be substantially higher during the mornings and evenings, but a PV array maxing out its production during those times also means you'll earn more for the net-metered energy your system produces! For these reasons, east- and west-facing arrays are becoming more common for net-metered grid-tied PV systems.

Dan Fink • Buckville Consulting

Courtesy Laurent Meillon, Capitol Solar Energy LLC • capitolsolarenergy.com

Tilt / Azmuth	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
90	81.11	81.94	82.43	82.52	82.21	81.62	80.71	79.56	78.15	76.51	74.66	72.64	70.41	67.96	65.41	62.7	59.83	56.96	53.91
95	81.11	82.33	83.18	83.66	83.67	83.37	82.72	81.82	80.6	79.08	77.33	75.32	73.16	70.73	68.13	65.34	62.38	59.27	56.14
100	81.11	82.7	83.93	84.73	85.1	85.07	84.64	83.95	82.91	81.55	79.86	77.93	75.78	73.33	70.65	67.87	64.8	61.51	58.21
105	81.11	83.06	84.63	85.77	86.46	86.7	86.5	85.97	85.07	83.86	82.31	80.39	78.25	75.85	73.08	70.14	67.06	63.69	60.14
110	81.11	83.42	85.31	86.73	87.72	88.23	88.3	87.91	87.14	86.02	84.57	82.74	80.58	78.16	75.41	72.31	69.1	65.63	61.96
115	81.11	83.76	85.94	87.67	88.89	89.68	89.95	89.76	89.12	88.08	86.72	84.93	82.72	80.32	77.57	74.4	70.99	67.43	63.55
120	81.11	84.06	86.53	88.52	90	90.99	91.45	91.46	90.97	90	88.71	86.99	84.81	82.26	79.47	76.31	72.79	69.01	65.02
125	81.11	84.35	87.09	89.3	91.02	92.21	92.82	92.96	92.65	91.8	90.53	88.86	86.73	84.13	81.22	77.99	74.37	70.46	66.28
130	81.11	84.64	87.6	90.03	91.96	93.3	94.08	94.35	94.13	93.38	92.14	90.51	88.47	85.88	82.82	79.49	75.78	71.68	67.31
135	81.11	84.88	88.06	90.7	92.79	94.29	95.22	95.58	95.48	94.83	93.61	91.94	89.86	87.33	84.3	80.82	76.96	72.7	68.18
140	81.11	85.1	88.47	91.28	93.52	95.19	96.22	96.68	96.63	96.09	94.97	93.27	91.11	88.54	85.46	81.9	77.93	73.54	68.78
145	81.11	85.29	88.84	91.79	94.13	95.94	97.11	97.65	97.65	97.13	96.09	94.46	92.23	89.54	86.41	82.77	78.62	74.08	69.15
150	81.11	85.44	89.13	92.21	94.66	96.53	97.79	98.44	98.44	97.91	96.89	95.32	93.16	90.41	87.14	83.38	79.13	74.46	69.37
155	81.11	85.58	89.37	92.55	95.09	97.01	98.35	99.08	99.15	98.59	97.52	95.94	93.81	91.09	87.77	83.95	79.57	74.73	69.49
160	81.11	85.66	89.56	92.81	95.37	97.36	98.74	99.52	99.69	99.22	98.11	96.43	94.25	91.51	88.16	84.23	79.76	74.76	69.32
165	81.11	85.73	89.66	92.94	95.58	97.57	98.98	99.78	99.98	99.56	98.5	96.8	94.52	91.67	88.2	84.18	79.59	74.54	69.05
170	81.11	85.75	89.69	93.01	95.65	97.64	99.01	99.81	100	99.57	98.5	96.8	94.48	91.51	87.98	83.93	79.34	74.23	68.66
175	81.11	85.73	89.68	92.96	95.58	97.55	98.89	99.59	99.68	99.15	98.04	96.38	94.15	91.31	87.79	83.71	79.05	73.84	68.23
180	81.11	85.7	89.57	92.81	95.39	97.31	98.59	99.2	99.22	98.71	97.64	95.99	93.76	90.92	87.43	83.28	78.55	73.38	67.81
185	81.11	85.61	89.42	92.57	95.07	96.92	98.15	98.81	98.88	98.35	97.21	95.51	93.18	90.22	86.68	82.59	77.98	72.82	67.26
190	81.11	85.49	89.2	92.23	94.63	96.38	97.6	98.25	98.33	97.79	96.65	94.81	92.35	89.32	85.77	81.73	77.14	72.13	66.73
195	81.11	85.34	88.89	91.82	94.08	95.78	96.94	97.53	97.52	96.89	95.56	93.64	91.24	88.35	84.9	80.85	76.34	71.41	66.14
200	81.11	85.15	88.54	91.31	93.44	95.07	96.14	96.6	96.43	95.58	94.2	92.36	90.05	87.21	83.74	79.81	75.46	70.65	65.51
205	81.11	84.93	88.13	90.71	92.72	94.22	95.14	95.43	94.98	94.08	92.77	91	88.71	85.8	82.41	78.61	74.39	69.76	64.83
210	81.11	84.69	87.67	90.03	91.9	93.23	93.95	94.01	93.55	92.72	91.43	89.61	87.18	84.25	80.95	77.24	73.1	68.67	63.95
215	81.11	84.42	87.14	89.29	90.99	92.13	92.65	92.57	92.13	91.26	89.86	87.87	85.36	82.59	79.4	75.75	71.75	67.45	62.91
220	81.11	84.12	86.58	88.49	89.97	90.88	91.19	91.04	90.54	89.56	88.01	85.88	83.52	80.8	77.62	74.08	70.29	66.19	61.89
225	81.11	83.81	85.97	87.62	88.86	89.56	89.68	89.46	88.83	87.69	85.9	83.91	81.65	78.95	75.8	72.4	68.74	64.81	60.71
230	81.11	83.47	85.32	86.66	87.7	88.16	88.11	87.79	86.99	85.0	83.69	82.01	79.71	76.92	73.83	70.58	67.06	63.28	59.36
235	81.11	83.11	84.64	85.73	86.46	86.7	86.5	85.99	84.97	83.5	81.87	79.91	77.52	74.68	71.79	68.62	65.2	61.68	57.96
240	81.11	82.76	83.93	84.73	85.19	85.19	84.8	84.08	82.91	81.36	79.69	77.64	75.09	72.43	69.64	66.6	63.35	59.97	56.45
245	81.11	82.36	83.2	83.69	83.88	83.59	83.01	82.04	80.7	79.15	77.36	75.17	72.67	70.22	67.46	64.44	61.34	58.15	54.74
250	81.11	81.97	82.43	82.62	82.5	81.92	81.11	79.93	78.45	76.84	74.95	72.65	70.34	67.87	65.12	62.19	59.27	57.55	53.03
255	81.11	81.58	81.67	81.51	81.07	80.19	79.12	77.81	76.19	74.46	72.43	70.14	67.86	65.37	62.64	59.9	57.13	54.2	51.21
260	81.11	81.17	80.9	80.39	79.59	78.4	77.11	75.63	73.86	71.99	69.83	67.57	65.27	62.77	60.14	57.6	54.88	52.06	49.29
265	81.11	80.77	80.14	79.23	78.08	76.62	75.1	73.4	71.45	69.39	67.18	64.91	62.62	60.12	57.64	55.14	52.52	49.68	47.26
270	81.11	80.37	79.35	78.06	76.56	74.83	73.04	71.11	68.93	66.79	64.52	62.23	59.86	57.41	55.03	52.6	50.07	47.69	45.19
Tilt	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90

PV efficiencies at various tilts and azimuths as a percent of ideal for a specific location.

Net-Zero-Energy Apartments

I'm part of a cohousing group in the very preliminary planning stages. We're contemplating designing a small apartment complex, with two- or three-story buildings that will include some common spaces and dwellings of various sizes for 12 to 16 families.

Some of us are environmentally oriented, and wonder what renewable energy and energy-efficiency technologies could be incorporated into our design. Is it out of the question to consider a "net-zero-energy" strategy for this community? We are looking at suburban properties in western Washington state.

James Thomas • via homepower.com

Making a net-zero-energy (NZE) apartment building in western Washington state, which gets 3 to 4 average daily peak sun-hours (that's the measure of total solar energy available) should be possible. Many people in your region already have NZE homes.

With a multistory building, it's crucial to maximize the solar roof area since that's your energy collector (unless your property includes an open field, in which case you could consider a ground- or pole-mount community solar installation). Design your buildings with a large south-facing roof and seek local advice about the best roof angle. Be sure to get good shading analysis to assess the solar window. And make sure that your south roofs are clear of all obstructions—locate all penetrations and structures, such as stacks, vents, and dormers, on other roof faces.

Heating will be your building's largest energy load, so achieving high thermal efficiency is paramount. Systems such as SIPs (structural insulated panels) for external walls can make a super-insulated, tight building easy to attain. And it's certainly possible with other methods, though in all cases you'll need a builder and contractors who understand and apply energy-efficient construction principles.

Heating with ductless minisplit heat pumps may be the most cost-effective option. These are tried-and-true, fairly straightforward to install, and use a small amount of electricity to grab heat out of the ambient air. Other heating options are more complicated and expensive, and also can compromise your building envelope and your indoor air quality.

A solar hot water system may be a good option for providing domestic hot water, though often it turns out that a standard electric water heater powered by solar electricity can be more cost-effective. I advise avoiding the glitzy appeal of heat-pump water heaters, since they are expensive and complicated, and there can be issues with their placement.

Choose carefully for all of your other loads. Don't buy anything that uses energy without taking a hard look at the options. Even if it's a higher up-front cost, choose the highest-efficiency product you can afford. Look at "life-cycle" cost—the cost of the appliance, how long it lasts, plus the cost of powering it for its lifetime.

If you design and build a conventional building, you will get conventional—that is, mediocre—energy performance. Most architects, builders, and subcontractors are not focused on energy efficiency. They design and build things "the way it has always been done" or cheaply. If you want a high-performance building, you'll need specialty professionals on your design/build team, and you or your consultants and contractors need to keep a significant focus on energy throughout the process. It can be done, but it requires attention to detail and a continuing focus on your goals.

Ian Woofenden • *Home Power* senior editor

Ian Woofenden

Thoughtful site planning and building orientation, plus energy-efficiency measures and renewable energy technologies, can combine to create a net-zero-energy housing development.

write to:

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This 20 kW PV system (shown partially completed) powers KILI radio on the Lakota Pine Ridge reservation.
Courtesy Remote Energy

giving

Powerful organizations are sharing their renewable energy expertise to do good work for people and the planet. *Home Power* profiles some of the influential solar movers and shakers that are helping create a better world.

GRID Alternatives

gridalternatives.org

In 2016, GRID Alternatives, a national nonprofit, partnered with the Richmond Housing Authority (RHA) to bring solar energy—and its cost savings—to one of the San Francisco Bay Area's most environmentally and economically disadvantaged communities. Triangle Court Apartments provides affordable housing serving families earning 50% or less than the area's median income. They are operated by RHA, the city agency that provides public housing options to low-income families, elderly residents, and people with disabilities.

GRID installed individual PV systems, ranging from 1.7 to 2.7 kW, on each of the 98 units, for a total capacity of 201.4 kW. The installation was combined with an energy-efficiency retrofit that qualified the development for no-cost PV systems through the State of California's Low-Income Weatherization Program. Together, the PV production and energy-efficiency measures are expected to reduce residents' energy bills up to 98%. The systems were installed between October 2016 and April 2017 and are expected to produce $1.88 million of electricity and prevent 3,800 tons of greenhouse gas emissions over their 25-year lifespan.

Courtesy GRID Alternatives

Courtesy GRID Alternatives (2)

Project Details

Project name: Triangle Court Apartments

System type: Batteryless grid-tied PV

Installer: GRID Alternatives Bay Area

Date commissioned: April 2017

Location: Richmond, California

Latitude: 37°N

Average daily peak sun-hours: 5.4

Systems' capacity: 201.4 STC kW

Average annual production: 223 kWh

Average annual utility bill offset: 87%

Equipment Specifications

Number of PV modules: 760

PV manufacturer & model: JA Solar JAP6-60-265

Module rating: 265 kW

Inverters: 760 Enphase Energy M215-60-2LL-S2X IG microinverters

Inverter rated output: 215 W per microinverter

Array installation: Flush-mounted on roof

Array azimuth: 81° or 261° (depending on roof orientation)

Tilt angle: 25° to 38° (depending on roof pitch)

GRID ALTERNATIVES

"I'm 65 years old and on a fixed income; the reduction of my electricity bills will help me greatly, as sometimes I have to struggle making ends meet. Thank you," shared one retired resident.

GRID and the City of Richmond have been partnering since 2011 to bring PV systems and job training to city residents. GRID coordinated with the city to qualify the Triangle Court Apartments and provided technical analysis, design, and installation.

They also worked with the property-management company to engage the residents of Triangle Court. Through GRID's unique people-first volunteer and workforce development model, local volunteers and trainees participated in the installations, gaining hands-on job experience in the local solar industry. Sixty-one job trainees received nearly 900 hours of training through the project, including students of local job training organizations Rising Sun Energy Center and Solar Richmond. The project also hosted GRID's weeklong intensive solar training program for women. GRID also provided direct energy-efficiency education for tenants to further increase their energy savings.

Grid-tied PV systems at the Triangle Court Apartments significantly offset residents' utility electricity bills.

Solar Energy International

solarenergy.org

Founded in 1991, Solar Energy International (SEI) has provided industry-leading technical training and expertise in renewable energy to empower people, communities, and businesses worldwide for almost three decades. SEI is an educational nonprofit specializing in online and in-person hands-on solar-electric trainings, ranging from small-scale systems to complex microgrids. SEI has trained more than 65,000 students in the solar industry, and its students have installed approximately 4,000 MW of PV capacity throughout the world.

Recent Programs & Projects

SEI's newest program, Solar Forward, powers rural Colorado communities into the future by starting or supporting solar markets. The program pairs an SEI technical adviser with a community nonprofit looking to grow the local solar market. The nonprofit receives a year of technical advising on solar initiatives, including a toolkit of resources developed by industry professionals.

As many rural communities in Colorado transition from coal-dependent economies, there is a critical need for these communities to build sustainable solutions for the future. A solar market has the potential to create jobs, insulate against rising energy costs from wholesale electricity suppliers, and create local energy resilience. For more information, see www.solarenergy.org/solar-forward.

On the Horizon

One of SEI's main goals is to continue to make its trainings more accessible (cost, language, and technology) to the world to advance the mission. Opening additional international campuses—including in Latin America and the MENA region—and expanding the Paonia, Colorado, campus is part of the overall strategy. SEI also continues to enhance the services to current students and alumni by formalizing employer partnerships to ensure job placement.

SEI strives to stay up-to-date on cutting-edge industry technology, and is working to develop industry-leading technical training with a focus on energy storage; system operations and maintenance; and other areas in the solar industry.

Growing a Global Presence

This year, SEI reached two milestones toward its mission of "a world powered by renewable energy" by launching a solar training center in Costa Rica and a PV lab-based training experience in Oman.

SOLAR ENERGY INTERNATIONAL

SEI's solar training center in Costa Rica.

Courtesy Solar Energy International (2)

Omani students get hands-on experience with solar electricity.

Project Details

Project: Centro de Capacitación en Energía Solar de SEI-CFIA

System type: Batteryless grid-tied PV

Installer: SEI

Date commissioned: April 2018

Location: Ujarras, Costa Rica

Latitude: 9.8°N

Average daily peak sun-hours: 4.5

System* capacity: 9.84 STC kW

Estimated annual production: 14,791 AC kWh

Equipment Specifications

Number of PV modules: 28

PV manufacturers & models: Trina Solar TallMax TSM-PE14; Trina Solar Honey TSM-PD05; Yingli Solar YL320P-35B

Module ratings: Trina Solar TallMax, 320 W STC; Trina Solar Honey, 270 W STC; Yingli Solar, 320 W STC

Inverters: Fronius Primo 3.8; SolarEdge 3800 with P370 optimizers; Enphase IQ 6 Micro microinverters with IQ Envoy communication gateway

Inverter rated output: Fronius, 3.8 kW; SolarEdge 3.8 kW; Enphase 0.28 kW per microinverter

Array installation: Fronius array: Schletter FS System ground-mount; SolarEdge array: SnapNrack 100 Roof Mount System; Enphase array: SnapNrack 100 Roof Mount System

Array azimuth: 180°

Tilt angle: 15°

*These three PV systems are tied to a single production meter.

Costa Rica. SEI opened its first International Solar Training Center in Costa Rica through a partnership with CFIA (Federated College of Engineers and Architects of Costa Rica) and CIEMI (College of Electrical, Mechanical, and Industrial Engineers). Since the beginning of SEI's Spanish program in 2013, SEI has trained more than 9,000 Spanish-speaking educators, empowering Latin Americans with solar education and increasing renewable energy access for their communities.

The Solar Training Center SEI-CFIA is located in the province of Cartago, Costa Rica, inside the facilities of CFIA's Integral Training Center Uxarrací. The center is equipped with modern tools to construct, commission, and test solar-electric arrays. Three on-site PV systems are configured in compliance with the U.S. *National Electrical Code (NEC)*, allowing students to learn about stringent design and safety parameters. Students are able to design and wire PV arrays from the roof up, using modern technologies and popular products available internationally. The center is constructed in compliance with OSHA regulations to model a safe working environment for the students' learning experience.

Muscat, Oman. This past spring, SEI and Shams Global Solutions (SGS), an Omani company, partnered to launch Oman's first certified PV training program. The program's first course, "PV101: Solar Electric Design and Installation (Grid-Direct)" was certified by Oman's Distribution Code Review Panel (DCRP) and supports applications to become a DCRP-approved Solar Professional. This DCRP certification is required for individuals who want to work as consultants or contractors for grid-connected PV systems in Oman's growing solar industry.

Since the first class in March 2018, 77 students from the energy industry, electrical utilities, and academia have completed the PV101 coursework, which introduces the core concepts of the design and installation of grid-tied PV systems, including solar site analysis, PV system components, mounting structures, system wiring, interface protection, and safety. The program plans to train up to 75 additional students before the end of the year.

This fall, for the first time, SEI's industry-leading "lab-yard" experience will be available in Oman, offering its first hands-on PV training in November. By the end of 2018, SEI's Middle East and Africa program will have offered trainings in Oman, UAE, Israel, Kuwait, and Egypt, through a combination of public and private courses. Plans are to expand training opportunities to Saudi Arabia.

Students at the Costa Rica campus receive expert training on modern PV system technologies.

Courtesy Solar Energy International (2)

We Care Solar

wecaresolar.org

Dr. Laura Stachel and Hal Aronson combined their skills in medicine and solar energy to create We Care Solar (WCS) in 2010. As a former obstetrician-gynecologist conducting public health research in a Nigerian hospital, Laura was stunned to see how the lack of reliable electricity contributed to maternal-newborn mortality. Hal had taught renewable energy in California for more than 13 years. He co-created Solar Schoolhouse, bringing solar curriculum to California schools, and also created California Youth Energy Services, a service learning program. When Hal designed a rugged solar-electric system for Laura's Nigerian colleagues, it transformed emergency obstetric care.

No woman should die giving life. But every year, 300,000 women and more than 1 million newborns die from pregnancy and childbirth complications. In hundreds of thousands of health centers lacking reliable electricity, midwives and doctors struggle to provide critical care in near-darkness, leaving health workers unable to detect life-threatening conditions or provide critical services. The consequences are tragic.

WCS makes solar power simple and accessible to clinicians. Their innovative Solar Suitcase, a complete solar-electric kit designed to meet the needs of health workers in under-resourced health facilities, was conceived by founders Hal and Laura. It includes medical lights, rechargeable headlamps, phone chargers, and a fetal heart-rate monitor to detect distress. With these devices, health workers report reductions in maternal and newborn mortality. Bright medical lights combined with solar power for medical equipment give health workers "the power to save lives."

Recent Projects & Programs

In 2018, WCS conducted Solar Suitcase programs in Uganda, Liberia, Tanzania, Nigeria, and Ethiopia. The programs include:

Courtesy We Care Solar (2)

Left: This midwife from Malawi now has clean, reliable solar electricity for lighting, phone charging, and fetal monitoring. Below: Women Solar Ambassadors lead solar installation trainings for Solar Suitcase programs.

- Conducting needs assessments to identify health centers in need of reliable electricity for childbirth
- Leading capacity-building workshops to train local technicians to install and maintain WCS technology
- Conducting installations in "last-mile" health centers and educating health workers to use WCS technology appropriately
- Monitoring and evaluating the impact of WCS programs

The work is collaborative; WCS partners with ministries of health, nongovernmental organizations, and United Nations agencies that are working to improve maternal and newborn health care in health centers without adequate equipment. By conducting training workshops, WCS builds local capacity in Solar Suitcase installation, operations, and maintenance. With this model, they have equipped more than 3,400 health centers with Solar Suitcases, trained 13,000 health workers, and improved obstetric care for an estimated 1.7 million mothers and their newborns.

On the Horizon

WCS's "Light Every Birth" initiative calls upon governments and international partners to ensure that all pregnant women have access to reliable electricity and lighting for safer births. WCS started national initiatives in two countries—Liberia and Uganda—working with international NGOs, ministries of health, and UN agencies. Sierra Leone, Tanzania, and Zimbabwe are the sites of the next Solar Suitcase programs.

Solar Suitcases in Sierra Leone

In Sierra Leone, maternal mortality rates are among the highest in the world. One in 23 women are at risk for dying during their lifetime from pregnancy and childbirth complications. With only 10% of the country having access to electricity, health workers providing nighttime care are often forced to rely on candles, kerosene lanterns, and flashlights. Critical procedures may be postponed until daylight is available.

Even before the Ebola outbreak in 2014, WCS was working to distribute solar power to dozens of health facilities around the country and conducting solar installation trainings with local technicians.

After Ebola, their work accelerated—more than 100 Solar Suitcases have reached "last-mile" (remote) clinics. This year, WCS is hoping to bring 100 more Solar Suitcases to health facilities in three districts of Sierra Leone, helping 10,000 mothers and babies in the next five years.

It costs approximately $3,000 to light up a health center with a Solar Suitcase for five years and to train local technicians how to install and maintain these devices. WCS primarily relies on funding from grants and individual donations.

What's in a Solar Suitcase?

PV modules: 40 W to 100 W; 12-volt

Charge controller: Morningstar ProStar, 15 A

Battery: Lithium ferrous phosphate

Lamps: Four; medical

The Solar Suitcase can be used as a mobile or permanent solar-electric system—the suitcase itself bolts to the wall and the modules can be mounted on a roof. An expansion kit provides additional lights for adjacent rooms.

"It is an out-of-the-box, plug-and-play experience. Someone who has never done anything with solar electricity can get the system running in less than a minute," Aronson says. "If they choose to use it for a permanent installation, then it can be fully operational within two hours of opening the kit. It is that easy to use."

"Health workers tell us they are no longer afraid to work at night, that they can do medical procedures with ease, that they can do the job they were trained to do," Stachel says. "Surgeons tell us they can perform surgeries more efficiently and safely. And mothers no longer need to include candles and kerosene as part of their birthing kits."

Courtesy We Care Solar

In Ethiopia, a newborn baby gets the gift of a well-lit, safe birth, thanks to the Solar Suitcase.


Courtesy Solar Electric Light Fund

Haitian instructors install a lab-yard array during a "train-the-trainers" course.

Remote Energy

remoteenergy.org

Remote Energy is a nonprofit organization with a mission to empower underserved and marginalized populations with the highest-quality, customized PV training programs and project support. Remote Energy works directly with technicians, NGOs, businesses, and other international agencies that use renewable energy to address issues related to jobs, health, clean water, education, gender equality, and poverty alleviation.

Each of the founders of Remote Energy—Carol Weis, Brad Burkhartzmeyer, Chris Brooks, and Jason Lerner—shared a vision to bring quality PV training programs to developing communities. Founded in 2017, Remote Energy consists of a team of multilingual professional solar installers, electricians, and PV trainers who specialize in technical capacity-building programs and PV system implementation. Together, they have conducted training activities in more than 25 countries throughout Africa, the Caribbean, Latin America, and Asia.

Recent Projects & Programs

Haiti, like many other developing nations, is poised for renewable-energy growth and the demand for a trained solar workforce is growing. Solar Electric Light Fund (SELF) recognized that need, found funding to start a national training center, and brought in Remote Energy to develop a two-year training program at Haiti Tec, a local polytechnic school in Port-au-Prince. Haiti Tec already had a strong electrical program and energetic teaching staff, but they lacked the technical capacity and materials needed to teach PV system design and installation. A comprehensive PV curriculum, designed by Remote Energy and delivered in French and Creole, was developed to prepare students for real-world work in the PV industry. It includes a hands-on laboratory where students practice installing, maintaining, and troubleshooting a variety of PV systems. Remote Energy also trained the instructors to ensure high-quality delivery and sustainability of the program. This year, 32 students graduated from the Haiti Tec National Training Solar Center as solar electricians, and half were women.

On the Horizon

Remote Energy is dedicated to training in other capacities. Its Women's Program focuses on women's-only PV classes to provide a comfortable and supportive atmosphere for women to gain hands-on experience from professional women instructors. In 2018, a solar lighting class was conducted in French for women from Benin and Niger. The PV systems they learned to build will provide them with light to study for their university exams.

Remote Energy also focuses on training the technicians and end users who are responsible for the PV systems at their facilities. This year, the organization worked with the Lakota Nation in South Dakota to install a 20 kW system for their community radio station and train local technicians. They also trained students and staff to install and maintain a PV system at a remote school in the Himalayas.

Remote Energy's team is passionate about developing and implementing training programs that foster sustainable PV projects in developing communities. They look forward to expanding their existing network of partners and will continue pursuing opportunities to empower people with RE education.

Solar Sustainability at SECMOL

This summer, Remote Energy cofounder and trainer Chris Brooks partnered with the Physics and Engineering Department of San Juan College to teach a hands-on PV training program and lead an off-grid installation at a school in the Indus Valley of Ladakh, a remote region in the northern Indian Himalayas.

The workshop included students from San Juan College and students and staff of SECMOL (Students' Educational and Cultural Movement of Ladakh) School. SECMOL has pioneered the reform of India's struggling governmental school system. The campus is an ecovillage that equips young Ladakhis, especially those from rural or disadvantaged

Right: **Students from Niger and Benin build PV-powered DC systems to provide lighting for taking university entrance exams.**

Courtesy Remote Energy

backgrounds, with the knowledge, skills, perspective, and confidence to choose and build a sustainable future. PV technology will prove to be a big part of this future, as recent Indian government initiatives aim to develop substantial renewable energy projects in the region.

The SECMOL campus had been struggling for years with an antiquated PV system that had broken modules, faulty wiring and components, and chronically undercharged batteries. Despite their solid grasp on energy efficiency and conservation, and a terrific solar resource, the students of SECMOL frequently ran a generator to supply their modest electrical loads.

The PV workshop was designed to meet this need. Students were introduced to the basic skills necessary to design, install, and maintain a standalone PV system. Special emphasis addressed crucial topics: system safety; battery selection, sizing, and maintenance; conductor types and sizing; overcurrent protection; and system integration. Each topic focused on PV system sustainability, which is critical in remote areas. As part of the learning process, the 12 students from San Juan College worked alongside staff and students from SECMOL School to install the critical system upgrades, which included a new battery bank, charge controller, and inverter. Overcurrent protection and disconnects were added. The PV modules and racks were repaired and rewired to a new MPPT charge controller. Larger AC wires were run from the power plant to the school.

The training workshop and installation proved to be a great success for everyone involved. The San Juan College students had the valuable experience of studying PV in the context of international, rural, sustainable development and the students of SECMOL now have the knowledge base and confidence to operate and maintain their new PV system. Plans are already being made for future PV trainings and projects in the region.

Chris from Remote Energy discusses module wiring with San Juan College and SECMOL students.

Courtesy Carl Bickford

Solar Supports the SECMOL School

Project name: SECMOL School PV system

System type: Off-grid

Installers: Students and staff of SECMOL School (India) and San Juan College (United States)

Date commissioned: June 20, 2018

Location: Phey, Ladakh, India

Latitude: 34°N

Altitude: 11,100 ft.

Average daily peak sun-hours: 6.2

System capacity: 2.88 STC kW

Average annual production: 5,210 kWh

Equipment Specifications

Number of PV modules: 36

PV manufacturer & model: Tata BP Solar 80 W

Inverter & charge controller: OutBack Power VFXR3048E, OutBack FlexMax FM80 charge controller

Battery bank: Luminous, lead-acid, 48 V, 300 Ah

Inverter rated output: 3,000 W, 230 VAC

Array installation: Pole mount; custom-built dual-axis tracker (azimuth-adjusted three times daily; tilt adjusted twice seasonally by the SECMOL students)

Solar Electric Light Fund

Solar Electric Light Fund

self.org

SELF taps into the sun—a universally distributed and carbon-free source of power—to help lead the effort to make clean, modern energy available to all—narrowing the divide that exists between the privileged and the poor. The organization designs and implements solar-energy solutions to assist those living in energy poverty with their economic, educational, health care, and agricultural development.

SELF was founded in 1990 by Neville Williams, a solar energy pioneer who has promoted solar power applications around the world since 1988. In 1997, Robert Freling assumed leadership of the organization and has served as its executive director ever since. Under Freling's leadership, SELF has installed more than 550 solar energy systems in 25 countries, making it one of the world's leading nongovernmental organizations that designs and implements solar energy-based solutions for those living without access to electricity.

Recent Projects & Programs

- Ghana and Uganda, United Nations Foundation: Solar-electrified 62 rural clinics.
- Haiti, CDC/Ministry of Health: Installed 145 solar-powered vaccine refrigerators.
- Haiti, National Solar Training Center: Created and established a two-year solar training program.
- Haiti, Hurricane Restoration: Facilitated 12 health center PV system repairs.
- Haiti, Fe-Yo-Bien: Established a PV microgrid for homes and businesses.
- Colombia: Invented and field-tested first excess-energy-harvest controls for solar direct-drive refrigerators.
- Colombia, Gunchukwa: Established a PV-based microgrid for an eight-building communal complex.
- Benin, Clean Water Stations: Designed and installed three solar-pumping systems.
- Benin, Solar Market Garden: Built 12 solar-powered drip-irrigation systems.

A traditional Arhuaco roof sits in contrast to a 6.8 kW PV array.

Solar electricity will help enhance the lives of Katansama's children.

Courtesy SELF (3)

Courtesy SELF

Solar Supports Indigenous Traditions

The Arhuaco people who live in the Sierra Nevada de Santa Marta mountains of northern Colombia have maintained their indigenous traditions over many centuries. Among those traditions is honoring their spiritual mandate to be nature's stewards. Intuiting that those in the industrialized world do not share their reverence for Mother Earth, they are motivated to teach us—their "little sisters and brothers"—by example.

Viewing conventional sources of power generation as corrupting and polluting, the Arhuaco reached out to SELF for an alternative source of clean, reliable electricity. SELF was invited by a community leader to make the case for using solar electricity to support modern heath-care services, educational resources, commercial opportunities, and more. This led to the spiritual elders giving it their blessing and asking for SELF's assistance.

Since 2011, SELF has worked with the Arhuaco, as well as the nearby Kogi and Wiwa peoples, to assess their energy needs. A survey of 12 villages led to 15 PV system installations. These installations generate clean electricity and provided hands-on solar training for community members, who now maintain the systems.

All of the installations had been in the Sierra Nevada de Santa Marta mountains where the Arhuaco have been living since colonial powers drove them from their ancestral coastal homes. When Colombia's civil war recently ended, the Arhuaco began to recover their ancestral lands. Of special significance is Katansama, a newly founded seaside village and their first direct link to the Caribbean in 500 years.

A village-wide assessment was carried out in January 2017 with support from Switch Energy Alliance, a nonprofit with the mission "to inspire the public to learn about energy, engage in informed conversations, and make smart decisions about our global energy future." Interviews with tribal community leaders revealed a desire to establish an indigenous cultural center and a digital library. The village also has a school complex and community social service buildings for which they wanted electricity.

In consultation with village leaders, SELF developed a PV microgrid plan. Phase 1 was completed in 2018 with a 6.8 kW PV system to power the school building complex that includes three classrooms, a dormitory, and a cafeteria. Phase 2 will power the communal social center buildings used for meetings, cooking, and microenterprises. Phase 3 will support the indigenous leadership center and digital library.

Interviews with village authorities provided sufficient information to estimate electrical load requirements for the Phase 1 school project, which was used to select appropriate PV system components. The seaside location poses a challenge for equipment due to corrosion from the salt air, and care was taken to select components with corrosion resistance, such as waterproof LED tube lights and wet-location-rated ceiling fans.

Katansama is located along the route to internationally recognized Parque Tayrona, a coastal and mountainous national park. With plans for an Arhuaco cultural center that will attract thousands of visitors annually, the village will have a unique opportunity to generate income for sustaining operation and maintenance costs of the community's battery-based PV systems.

On the Horizon

- Nine new water stations have been funded for installation in Benin.
- Solar-direct vaccine refrigerators coupled with energy harvest controls are being field-evaluated per WHO requirements in Senegal beginning late 2018.
- Funding is being sought for continued indigenous projects in Colombia, including the next two phases of Katansama microgrids, as well as solar power for the Gunchukwa Health Center.
- Funding is being assembled to start a program in Uganda to use solar applications in an effort to curtail sexual violence against women and girls who collect water and fuel wood for their households.

PV-Powered School in Colombia

Project name: Katansama School Complex, Colombia

System type: Stand-alone PV minigrid

Installer: SELF

Date commissioned: April 2018

Location: Katansama, Colombia

Latitude: 11.25°N

Average daily peak sun-hours: 4.25

System capacity: 6.8 kW, STC

Estimated annual production: 8,000 kWh

Number of PV modules: 24

PV manufacturer & model: REC 285 TP2; 285 W

Inverters: Two OutBack FXR3048

Inverter rated output: 6 kW

Battery: GS Yuasa SLR-1000-2, advanced lead-acid nanocarbon chemistry; 48 VDC; 1,000 Ah at C/10

Array installation: Preformed Line Products pole-mount

Array azimuth: 0°

Tilt angle: 10°

Check out this SELF project at **bit.ly/SELFvideo.**

Courtesy TWP

Trees, Water & People

treeswaterpeople.org

TWP's mission is to "improve lives by helping communities protect, conserve, and manage their natural resources." TWP recognizes that natural resources are best protected when local people play an active role in their care and management. TWP also believes that conservation can, and should, improve the livelihoods of local people. The organization uses an enterprise approach to natural resource management to create jobs and protect the environment for future generations.

Founded in 1998 by foresters and friends Stuart Conway and Richard Fox, TWP originally sought to curtail deforestation. Stuart and Richard soon realized that without addressing the underlying causes, they would never be able to implement lasting solutions.

Recent Projects & Programs

TWP's national Tribal Lands Solar Warrior training is a multistate program providing culturally tailored, hands-on solar energy education and opportunities to Native American students. With the goal of increasing Native American participation in higher education, STEM careers, and renewable energy professions, TWP hopes to break the cycle of energy dependence that has characterized Native communities for generations. In a short time, TWP has been able to tap networks across the West to build support for this work and to grow the RE ecosystem in Indian Country.

Since 2017, with EPA funding, TWP has trained 14 middle school, high school, and university instructors in South Dakota—at The Pine Ridge Girls School, Little Wound Middle and High Schools, and Sinte Gleska University—reaching hundreds of young people in the first year. TWP training uses We Care Solar's Solar Suitcase, a standalone DC power system. The accompanying curriculum is a robust pedagogy that demystifies PV energy, and helps young people hone their creativity and problem-solving skills to address community energy needs.

Trees, Water & People
Helping people and the planet

What's in the Solar Suitcase?

PV module: 100 W Dasol PV module

Charge controller: 10 A, 12 VDC; low-voltage disconnect

Battery: 12 V, 12.8 Ah; lead-acid

Accessories: 2 WCS lighting connectors; two 12 VDC lighter/accessory sockets; two expansion ports. PV cable and installation hardware are included.

Solar Warriors—Energy for Tribal Lands

Many of the people TWP works with live in indigenous communities where rampant poverty and historical marginalization keep opportunities out of reach. While rich in natural resources, tribal lands in the United States have historically suffered from a lack of access to energy, employment, and quality education.

This year, the TWP tribal school program features science, technology, engineering and mathematics (STEM) curricula. Recognizing that to heal the land, we must first heal the people, TWP has developed an approach to learning that takes care to bridge the cultural gap between Native American communities and solar technology. TWP has created a unique solar curriculum that integrates social, emotional, and behavioral wellness.

Solar Warrior Energy Camps, led by TWP National Director Eriq Acosta, use the Solar Suitcase kit to provide hands-on experience with basic tools, wiring, charge controllers, circuits, multimeters, and PV modules. Students build skills toward PV system testing and troubleshooting. The approach strikes a balance between traditional wisdom and a core STEM curriculum, helping youth to develop technical skills while reinforcing traditional indigenous values of community, service to others, appreciation for the magic of the natural world, and reverence for the sun.

At this year's first Solar Warrior Energy Camp in the Hoopa Valley Reservation, California, all of the students who attended said that they were interested in taking the next level of solar technology training and said that the weeklong experience made a difference in how they see the world. Most said that they also learned something new about themselves.

This work, coupled with TWP's historical reforestation projects, goes hand-in-hand to cultivate a regenerative cycle of energy equity and conservation. In 2018, TWP planted more than 33,000 trees on North American tribal lands. The Solar Warrior Energy Camp was also followed by a PV system installation at the tribally owned Hoopa Valley Campground with the help of all the students in the workshop.

The organization works through alliance with partners at We Care Solar, Cal State East Bay, and the Native Indian Youth Leadership Project. Each contributes in their specialized arena of expertise to achieve common goals.

On the Horizon

In 2019, TWP plans to host five to seven Solar Warrior Energy Workshops, working with four distinct tribal communities, including the Santa Fe Indian School, the Pine Ridge Reservation, Hoopa Valley Reservation, and the Ojibwe White Earth Reservation.

Courtesy TWP (3)

Courtesy Get Charged Up

The Solar Foundation

thesolarfoundation.org

The Solar Foundation's (TSF) mission is to accelerate adoption of the world's most abundant energy source through leadership, research, and capacity building, creating transformative solutions to achieve a prosperous future in which solar and solar-compatible technologies are integrated into all aspects of our lives.

Recent Projects & Programs

TSF works to advance solar energy through essential research products, educational outreach, and leadership.

TSF's annual *National Solar Jobs Census* counts the number of solar jobs nationwide and at the state and local levels, while providing comprehensive data on the U.S. solar workforce. In 2017, TSF published the first annual "Solar Industry Diversity Study," which charted the demographics and career paths for women, people of color, and veterans. This report provided the first benchmark for solar workforce diversity and recommendations for how the industry can improve

TSF also leads the Solar Training Network, a groundbreaking workforce development program that connects solar job seekers, training providers, and solar employers. This program is bridging the gap between supply and demand in the solar jobs market.

TSF works with hundreds of local governments to encourage solar development. Its SolSmart program provides no-cost technical assistance to help cities, counties, and small towns make solar more affordable and accessible. Its solar schools research, newly updated in 2017, provides a comprehensive inventory of K-12 schools with PV systems and a how-to guide for schools interested in going solar. TSF's CivicPACE program helped bring property assessed clean energy (PACE) financing to tax-exempt organizations, such as nonprofits, affordable housing, faith-based institutions, and schools.

And, finally, through initiatives such as Solar Saves Lives, TSF is working on research and education to help communities improve resilience as they plan for and respond to disasters. One of the most detrimental impacts of a major disaster is the loss of electricity—especially if power remains out for days, weeks, and months. Solar and solar-plus-storage technologies can be life-saving, helping provide immediate relief for communities while strengthening their energy infrastructure over the long term.

On the Horizon

Through November 2018, TSF will be conducting its 2018 *National Solar Jobs Census* survey. Any solar employer—regardless of whether they have previously provided data for the Census survey—can take the survey at http://www.solarjobscensus.org.

At SPI 2018, TSF and its industry partners launched SolarAPP, an initiative aimed at streamlining and decreasing costs of PV system permitting, inspection, and interconnection. And finally, TSF will continue to fundraise for and complete solar-plus-storage projects on more than 60 medical clinics in Puerto Rico through its Solar Saves Lives initiative.

Saving Lives with Solar in Puerto Rico

The Solar Saves Lives initiative (http://www.solarsaveslives.org) was launched by TSF, the Clinton Foundation, Operation Blessing International, Direct Relief, the Hispanic Federation, and Puerto Rican organizations like solar installer New Energy Puerto Rico and the Asociación de Salud Primaria de Puerto Rico to coordinate the delivery and installation of donated PV and energy-storage equipment to critical infrastructure impacted by hurricane-caused power outages. Government and civil society partners in Puerto Rico emphasized power restoration and the installation of backup power sources as a critical step for the continuity of social services and economic activity on the island.

The SOLAR FOUNDATION™ for a bright future

The objective of Solar Saves Lives is to use solar technology to help Puerto Rico rebuild and create more resilient communities. This year, Solar Saves Lives' partners completed the installation of PV and battery storage systems at several health clinics in Puerto Rico, including:

- Migrant Health Center Western Region, Maricao—18 kW PV system and 40 kWh battery.
- Corporacion de Servicios Medicos Primarios y Prevención de Hatillo, Utuado—15.8 kW PV system and 20 kWh battery.
- Profamilias Clinica Celestina Zalduondo, San Juan—25 kW PV system and 40 kWh battery.
- Profamilias Clinica Iella, San Juan—19.5 kW PV system and 40 kWh battery.
- Migrant Health Center Western Region, Las Marías—34.7 kW PV system and 40 kWh battery.
- Centro de Salud Familiar Dr. Julio Palmieri Ferri, Inc., Guayama—43.6 kW PV system and 40 kWh battery.

The first solar-plus-storage system was installed at the Migrant Health Center in Maricao, one of several medical centers in urgent need of reliable electricity. This nonprofit clinic is the only medical facility serving a community of more than 6,000, and is committed to providing medical services regardless of an individual's ability to pay. Solar Saves Lives secured donations for and installed an 18 kW PV system with a 40 kWh battery on this clinic in March 2018. This project was made possible through contributions from Direct Relief, Soltec, and Variety Energy. New Energy Puerto Rico installed the system pro bono. Justine Burt of Palo Alto, California, and the nonprofit Get Charged Up led a successful crowdfunding effort to support this project through individual contributions.

Despite the progress to date, the work in Puerto Rico is just getting started. There are more than 60 federally funded medical clinics on the island and Solar Saves Lives seeks to install solar-plus-storage systems on as many of these as possible. Their ability to do so depends in large part on the generosity of solar companies and other supporters.

Solar Saving Lives in Puerto Rico

Project: Migrant Health Center, Western Region

System type: Battery-based PV

Installer: New Energy Puerto Rico

Date commissioned March 2018

Location: Maricao, Puerto Rico

Latitude: 18.17°N

Average daily peak sun-hours: 5.13

System capacity: 18.02 kW STC

Average annual production: 33,704 kWh

Average annual utility bill offset: 40%

Equipment Specifications

Number of PV modules: 56

PV manufacturer & model: Jinko Solar JKM315W

Module rating: 315 W STC

Inverters: SMA SB5000TL

Inverter rated output: 4.6 kW

Array installation: Unirac Solarmount LT w/ Ejot Anchoring

Array azimuth: 180°

Tilt angle: 5°

Battery: Two Tabuchi EIBS16GU2; 20 kWh each

Watch a video highlighting the Maricao project at **http://www.solarsaveslives.org.**

The solar-plus-storage system on the Migrant Health Center improves energy resilience for the residents of Maricao.

Courtesy Get Charged Up

Track Your Energy Use & Save

by Monali Mujumdar

Comment & Discuss this article @ homepower.com/188.34

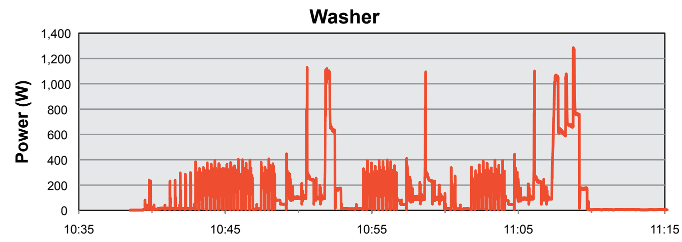
According to the Energy Information Administration (EIA), U.S. homeowners spend more than $1,300 on electricity each year. But there's a smart way to save, and that's by knowing exactly what is consuming electricity, and when—and making changes to your energy-use habits.

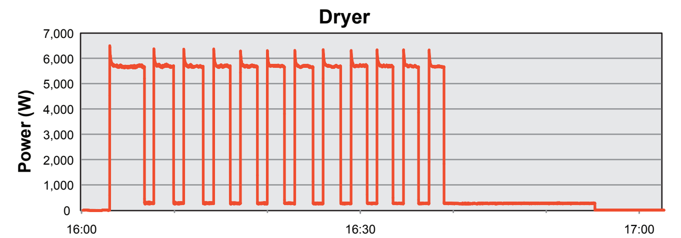
Courtesy Powerley

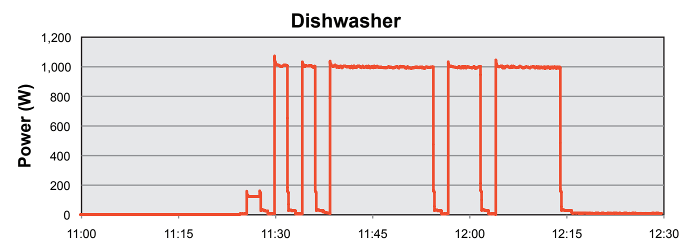
Efficiency upgrades, such as replacing old lighting and appliances with Energy Star models, as well as upgrading HVAC equipment, can curb energy use and costs. But studies have shown that homeowners receiving regular feedback of their energy usage are more likely to make behavioral changes for even greater utility bill savings.

Most monthly utility bills show some energy-use information and, in the best cases, may offer additional details, such as daily consumption, annual trends, and comparison with neighbors. However, having easy access to real-time usage data is far more effective in showing homeowners how their activities are affecting energy consumption.

Traditionally, submeters were used for real-time information, but their popularity is diminishing because they are expensive and difficult to install. Modern home energy-monitoring systems are comparatively inexpensive, easy to install, and can even show usage data on a smartphone. Some creative products allow users to interface with other smart devices, such as Amazon's Alexa virtual assistant or Philips' Hue lighting control app, making home energy monitoring an engaging experience.







Every appliance has a unique electrical signature when switched on or running. Disaggregation uses statistical methods to extract each appliance's energy consumption data from the entire home's energy signal.

Data Disaggregation

While most home energy-monitoring devices show whole-home energy usage in real time, some can show energy usage of individual appliances—called disaggregated data. George Hart, a mathematics professor at MIT, discovered that appliances have unique signatures when switched on or running. Using these signatures, he found that it was possible to extract data on the energy consumed by each appliance from the whole home's energy signal using "machine learning"—in which a computer program uses basic assumptions to predict which appliances are in use and then adapts continually as more data becomes available.

Initially the machine-learning algorithm could distinguish only between on and off states. As statistical methods evolved, algorithms distinguish between various states of appliances—for example distinguishing the signatures of a dishwasher's wash, rinse, and dry cycles. The technique—nonintrusive load monitoring (NILM)—is commonly used in HEM systems and can be fairly accurate in distinguishing between the appliances if they are large loads or have a distinctive signature. But as appliance efficiencies improve, load profiles are getting smaller and more similar, making NILM more difficult. Homeowners interested in HEM devices that have disaggregated data reporting capabilities should check the vendor website and see what appliances can be distinguished accurately.

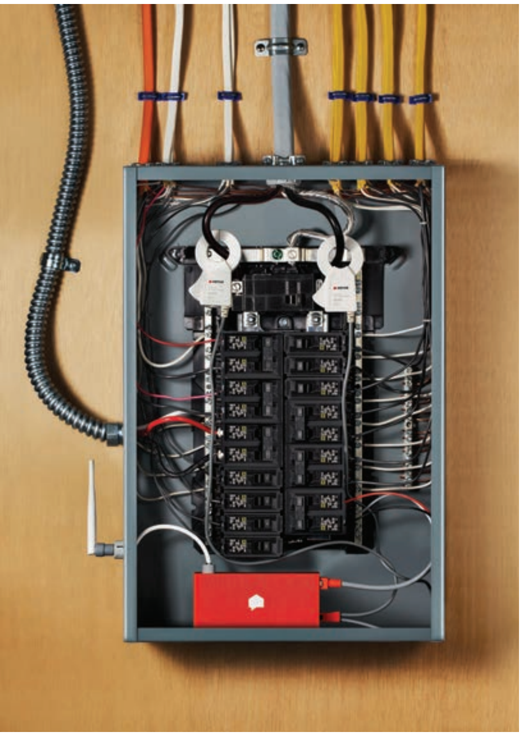
What's Available

Some meters record energy use of a single appliance at a time. For example, the widely available P3 International Kill A Watt ($22.99) measures power draw in watts or kilowatts (W or kW) and energy consumption in watt-hours or kilowatt-hours (Wh; kWh).

Courtesy P3 International

Watt-meters like the P3 Kill A Watt can measure watts, volts, amps, kilowatt-hours, and frequency, and can even calculate energy costs, but they can only do it for one appliance at a time.

Another strategy for measuring electricity consumption is installing a submeter in the breaker panel. Submeters measure current in individual circuits with current transducers (CTs) clamped around the circuit wires to sense current. Voltage measurements are taken directly on the breaker terminals. The calculated consumption is transmitted wirelessly to a display mounted within range. Some submeters can also provide instantaneous voltage and current readings, providing accurate energy consumption data. But they can be expensive ($1,000 to $5,000 per circuit), difficult to fit in the breaker panel, and require an electrician to install them.



Modern home energy monitors, like this one from Sense, use current sensors that can easily be clamped around the main power lines, and take their voltage measurements on the breaker terminals. A transmitter routes data wirelessly to an app, which shows energy-use details from individual appliances. Some home energy-monitors can also track PV system production.

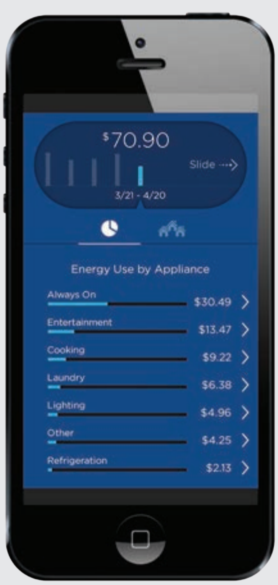
Courtesy Sense (2)

Utility Energy Monitoring

Utilities may also provide home energy use information. Many have online portals that can provide data such as a household's monthly energy consumption, daily outside temperature, and annual energy trends, as well as a comparison with the previous year. But these methods often lack the granularity that can help people make behavioral changes, and they lack personalized notifications. As a result, utilities are partnering with third-party vendors to provide disaggregated data to their customers. These solutions are usually available to customers for free or at a minimal cost.

Bidgely and Powerley are two solutions that measure power and energy, yet don't require any hardware be installed at the residence. Instead, these vendors acquire a home's smart-meter data from the utility and disaggregate it using proprietary software, sometimes in conjunction with data from other devices like smart thermostats. Users can access their energy-use information through proprietary apps, emails, or text alerts. Bidgely and Powerley are compatible with voice-enabled devices, such as Alexa or Google Assistant, and can answer many energy-use-related questions, such as anomalies in energy use, the projected energy bill for the month, and tips to reduce energy consumption.

Copper Labs' approach collects data directly from the user's meter (rather than getting smart-meter data from the utility). Its hardware device—Copper—has to be installed within 20 feet of the meter. It uses radio frequency to read data from the meter and then uploads it to the cloud via a home's Wi-Fi network. Copper disaggregates data in the background, but provides only whole-home energy use in real time to customers. Additionally, it can track PV energy production and the energy-behavior patterns of homeowners, and provides tips to reduce consumption.



Courtesy Bidgely

Left: Bidgely's utility-based energy monitor is gaining wide implementation and can disaggregate data from either utility smart meters or analog meters.

Courtesy Powerley

Developed to be implemented strictly by utilities, Powerley offers energy-management means in addition to monitoring.

Some home energy-monitoring products are easier to install, but still require an electrician. Instead of using multiple CTs, these systems have only one pair clamped around the main lines, and voltage is measured at the breaker terminals. Devices that transmit the signal wirelessly to the cloud are also small and fit in the breaker box. There are numerous devices available online for $250 and up.

Home energy-monitoring manufacturers are making energy data easy and convenient to access. Many newer energy monitors sync with a proprietary app, allowing users to view the data from a computer or mobile device. However, energy-use data isn't the only thing energy monitor apps can report. Reminders can be sent if usage exceeds a certain threshold or automated alerts can notify users if unusual energy consumption is detected. The Sense device can detect the energy signature of an iron, for example, and notify you if it has been on for a certain period of time. Homeowners can monitor their PV systems' production using Sense Solar, which is an upgraded version of the Sense energy monitor. With a thermostat that connects to a home's smart meter, HolHom can control energy use. Once energy-conservation settings are configured, it can reduce the thermostat setting when the home is using energy at a higher rate.

Courtesy Copper Labs

Right: Copper Labs' device is placed within 20 feet of a smart meter, and provides real-time energy use information by reading data using radio frequencies and sending it to a smart device in a user-friendly format.

Home Energy-Monitoring Systems

Types	Brands	Cost	Data Granularity	Difficulty of Installation	Availability
Submeters	EKM Metering, E-mon, Inovonics, Leviton, Schneider	$$$	✓✓✓	✖✖✖	To everyone
Smart-meter-based	Bidgely, Blue Line Innovations*, Copper Labs, Powerley	$	✓	✖	Through utility only
Sensor-based	Curb, Efergy, Ecoisme, Mirubee, Neurio, Sense, SiteSage, Smappee	$$	✓✓✓	✖✖	To everyone

*Blue Line Innovations is available in stores.

Select an energy-monitoring system that's right for you. Several energy-monitoring solutions are available for homeowners to choose from that vary in the method for collecting energy use data, which impacts their cost, installation, and data granularity. Some solutions are available via online stores or the vendor website, while some are available through utility-vendor partnerships.

Some energy-monitoring devices can be programmed to alert time-of-use (TOU) utility customers when their electricity has shifted to a higher rate. Many utilities are now using dynamic pricing or TOU rates to bill their customers—when overall electricity demand is high, customers are charged a higher rate. When demand is low, rates are lower. For example, in California's Pacific Gas & Electric utility's territory, residents are charged a higher rate per kWh between 4 and 9 p.m, when there's a greater demand for utility electricity. Sense's system can send notifications to users' smartphones, and other products provide a visual indication on a separate monitor. Rainforest Automation's EMU-2 can monitor peak demand and its "traffic light" display indicates real-time power draw via red, yellow, or green lights. Ovo Energy's In-Home Display shows real-time energy use and cost by connecting to the home's smart meter. AzTech Associates' In-Home Display has a light arc at the top of the display that pulses at a higher rate if power draw increases and changes color from yellow to red as the price of electricity increases.

Energy-Monitoring Trends

Technological advances in energy monitoring have shaped the way we measure and receive energy-use information. No longer do we have to rely on just the monthly utility bill or use submeters for granular data. New developments have made installation of monitoring devices easier and have brought real-time energy monitoring to our communication devices. Notifications can be personalized and actionable so users know exactly what needs to be done to reduce consumption. Manufacturers are also integrating other equipment data, such as from PV systems, to track energy generated. Products meet the needs of a wide audience, ranging from those who just want a simple indication of their energy use to tech geeks who want to build their own monitoring systems.

IFTTT (If This, Then That) is a web service that allows users to design applets (programs) that enable two IFTTT-compatible devices or software products to communicate with each other. Users can design their own alerts or notifications for a particular

Courtesy Efergy

Efergy's display shows a variety of conditions, including the amount of greenhouse gas produced per kilowatt-hour.

Mirubee is able to disaggregate the electrical information from various appliances to allow for fine-tuning of energy consumption.

Courtesy Mirubee

Courtesy Smappee

IFTTT, a web service to connect compatible devices, allows users to design their own response to energy usage. An energy monitor like Smappee Pro reads energy-consumption data from smart meters. It can then send a signal to change the color of an IFTTT-compatible lamp (inset) if a setting is exceeded, or give an audible alert via your smartphone if a certain appliance is turned on.

signal sensed by another device. An IFTTT-compatible monitor, such as Neurio, Sense, or Smappee, can measure a home's energy consumption and send a command to another IFTTT-compatible device to perform an action, such as signaling a certain color of bulb to illuminate if a setpoint is exceeded. LifX, Philips Hue, and ORBnext are IFTTT-compatible color-changing lamps.

The command could be an audible alert through an IFTTT-compatible voice-controlled device, such as Amazon Echo and Google Assistant. With the number of IFTTT-compatible devices increasing, the possibilities are many for the techy consumers to develop their own systems. A drawback with using IFTTT is that there can be a lag—from 2 to 15 minutes—between compatible devices, since the signal has to first go to the IFTTT cloud.

Interest in energy-use information appears to be increasing. As technology advances further, installing sensor-based monitors may get even easier. Improvements in NILM and machine-learning algorithms will increase the accuracy of disaggregated data. With the world moving toward the Internet of things and an interest in smart homes, energy monitors will evolve to integrate other equipment such as smart LEDs and smart thermostats.

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homepower.com/188.40

A2W

Air-to-Water Heat Pumps

Efficiency & Versatility

Courtesy Jaga;
inset photo: SpacePak

by John Siegenthaler

In 2016, there were approximately 2 million air-to-water (A2W) heat pumps installed globally, with the largest markets in Europe and Asia. The U.S. market is a tiny fraction of the global market, mostly due to its relatively few homes with low-temperature hydronic heating.

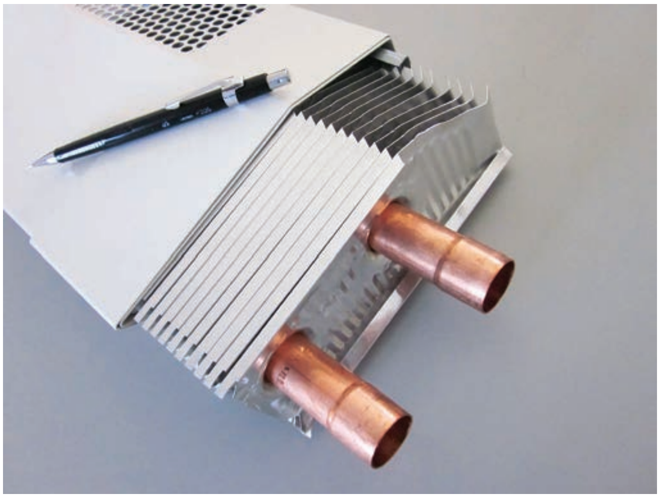
With increasing interest in net-zero-energy (NZE) homes, state renewable energy generation requirements, and carbon-dioxide reduction goals, heat pumps of all types will play increasingly important roles in heating and cooling systems. Air-to-water (A2W) heat pumps can compete with geothermal water-to-water heat pumps, especially in an unsubsidized market. They will also compete with air-to-air ductless minisplit heat pumps (MSHPs) based on their versatility and the comfort they offer.

While air-to-air (A2A) heat pumps and forced-air furnaces deliver heating and cooling using a blower, those systems may introduce drafts, noise, and dust. They also contribute to temperature stratification (warm air at the ceiling; cold air at the floor); higher rates of air leakage and heat loss; and lowered humidity. Hydronic distribution systems supplied by A2W heat pumps avoid many of these disadvantages because they distribute heating or cooling using low-temperature (120°F or less) emitters that do not create high air flows. If hydronic heating is a priority, your choices are either an A2W heat pump, a geothermal system, or a boiler-based system. When coupled to low-temperature radiant panels, A2W can provide excellent heating comfort. Unlike boilers, they can also supply hydronic cooling.

A2W Heating & Cooling

An A2W heat pump, in heating mode, absorbs low-temperature heat from the outside air and delivers higher-temperature water to the building's hydronic distribution system—usually radiant floor, wall, and ceiling panels; panel radiators; or fan-coil convectors. In cooling mode, the same heat pump delivers chilled water (or water/antifreeze solution) to air handlers with blowers to cool and dehumidify the building.

This heating-only emitter has the look of an electric baseboard, but has heat-pump-driven thermal performance.



Courtesy SpacePak

A2W System Configurations

Monobloc

A monobloc-style heat pump is an A2W heat pump supplied as a single, self-contained unit. Because monobloc-style heat pumps are precharged with refrigerant, they only require water piping and electrical connections during installation. As such, they can be installed without need for refrigeration-charging equipment, such as vacuum pumps.

Split-System

A "split-system" A2W heat pump is a variation that has refrigerant tubing running between the outdoor unit and an indoor unit. When connected by the these tubes, the outdoor and indoor units constitute the heat pump. Split-system A2W heat pumps do not require antifreeze because only the indoor unit contains water. Installation of any split-system heat pump requires a refrigeration technician to properly evacuate the refrigerant tubing and ensure that the correct amount of refrigerant is in the system.

Facing page: A Jaga Briza fan-coil emitter provides both heating and cooling from hydronic input. Inset: A SpacePak Solstice monobloc A2W heat pump.

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This wall-mounted air handler can be coupled to an A2W heat pump to provide space heating and cooling.

Cooling

In cooling mode, A2W heat pumps produce chilled fluid temperatures as low as 42ºF. That fluid can be routed to one or more air handlers or fan coils in which the chilled fluid absorbs heat from interior air and reduces its humidity.

During cooling, the heat pump's "source" is inside air. In this case, the functions of the two heat exchangers in the refrigerant circuit are reversed compared to when in heating mode. The heat exchanger that served as the evaporator in the heating mode becomes the condenser in cooling mode; and the condenser becomes the evaporator. This swapping between the heat exchangers is accomplished using an electrically operated reversing valve inside the heat pump.

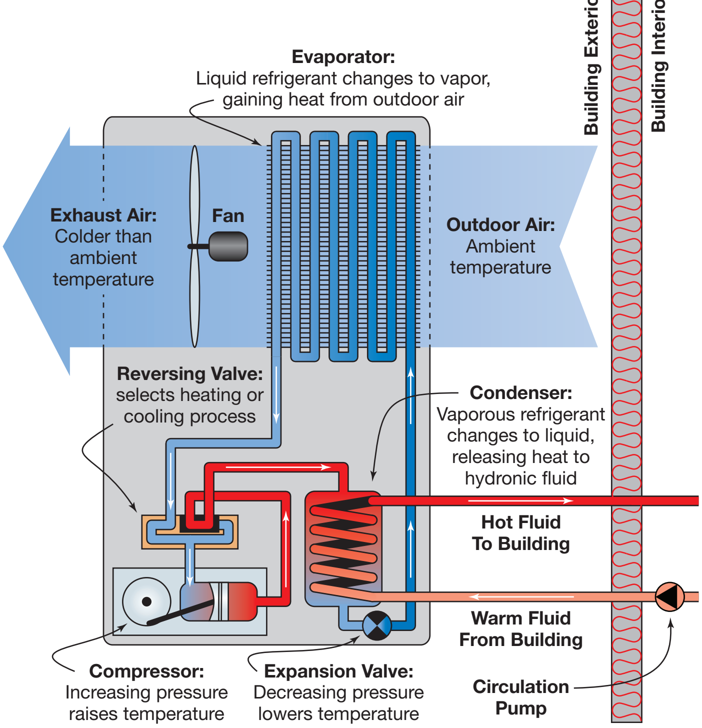
Heating

In heating mode, some A2W heat pumps can produce water temperatures up to 130ºF, even when the outdoor temperature is near 0ºF. This allows a wide variety of hydronic heat emitters to be used. In some systems A2W heat pumps can also provide some or all of a building's domestic water heating. With a suitable heat exchanger, heat can also be supplied to an ancillary load, such as heating a swimming pool or hot tub.

In heating mode, an A2W's liquid refrigerant absorbs low-temperature heat from outside air, which is blown across the evaporator coil by a fan. The absorbed heat vaporizes the liquid refrigerant. This refrigerant vapor passes through a reversing valve to an electrical-motor-driven compressor, which increases the vapor's pressure and temperature. As the now-hot refrigerant vapor exits the compressor, it does a U-turn through the reversing valve, and enters another heat exchanger called the condenser. A stream of water or an antifreeze solution is pumped through the other side of the condenser. The hot refrigerant vapor transfers heat to this fluid, and in the process, condenses back into a liquid. The liquid refrigerant then passes through a thermal expansion valve (TXV), where its pressure and temperature are reduced to the condition where this cycle description began. The refrigerant sealed within the heat pump is constantly flowing through this cycle whenever the heat pump is operating.

A2W Heat Pump Operation

Monobloc Unit in Heating Mode



Heating & Cooling Performance

Heating Performance

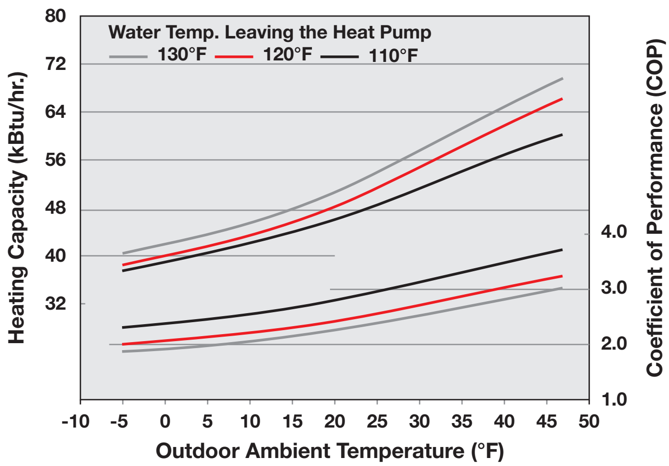
Heating capacity and coefficient of performance (COP) are two measures of how efficiently an A2W heat pump moves heat from outside air to interior water. Heating capacity is the rate, expressed in Btu per hour, that a heat pump can deliver heat to a building. A heat pump's "rated" heating capacity is based on operating conditions that are specified by industry standards.

The heating capability the A2W delivers at any given time could be higher or lower than the rated heating capacity, depending on the operating conditions. The colder the outdoor air temperature and the higher the temperature of the fluid leaving the heat pump, the lower its heating capacity. Hydronic heat emitters like radiant panels, which can operate at relatively low fluid temperatures, are a good match for the performance of A2W heat pumps.

A heat pump's COP is the number of units of energy output the heat pump delivers for each unit of electrical energy input. For example, a heat pump operating at a COP of 3.0 delivers three units of useful heat output for each unit of electrical energy input. Like heating capacity, the colder the outdoor temperature and the higher the temperature of the fluid leaving the heat pump, the lower its COP. Heat pump manufacturers provide tables or graphs that show heating capacity and COP as a function of outdoor temperature and different fluid temperatures leaving the heat pump.

Heating Capacity & COP

Data courtesy SpacePak



This example heat pump, operating at 0°F outside air temperature and with a leaving fluid temperature of 120°F, provides a heating capacity of 40,000 Btu per hour and operates with a COP of about 2.0.

Cooling Performance

Cooling capacity and energy efficiency ratio (EER) describe the cooling performance of A2W heat pumps. Cooling capacity is the rate at which the A2W heat pump absorbs heat from the fluid stream passing through its evaporator. The rated cooling capacity gives the amount of heat absorption under specific operating conditions, such as 44°F chilled-water temperature and 95°F outdoor temperature. The cooling capacity can be higher or lower than rated, based on current operating conditions. Cooling capacity decreases as the temperature of the chilled fluid leaving the heat pump decreases. It also decreases as the outdoor air temperature increases. The higher the chilled-water temperature can be and still meet the building's cooling and dehumidification requirements, the higher the heat pump's cooling capacity.

The energy efficiency ratio (EER) is the heat pump's cooling capacity divided by the electrical power (W) supplied to the heat pump. The higher the EER, the greater the cooling capacity per watt of electrical input power. High EERs are always desirable. Like cooling capacity, the EER of an A2W decreases with increasing outdoor temperature. It also decreases as the chilled fluid temperature leaving the heat pump decreases.

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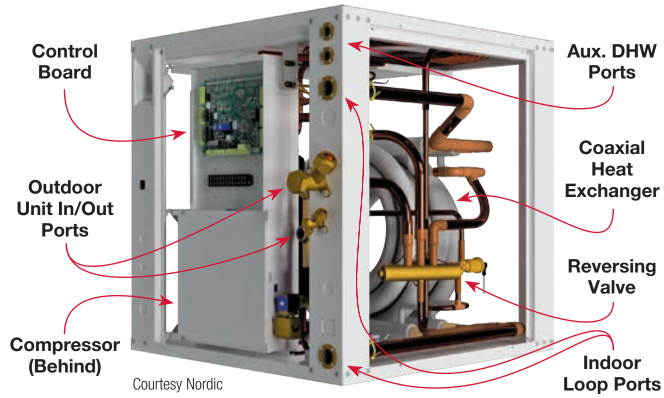
Left: The outdoor portion of a split-system heat pump by Nordic. The stand elevates the unit above snow level. Refrigerant tubing and electrical cables pass through the wall to the indoor unit.

Right: A cutaway of the Nordic split-system interior unit.



Courtesy Nordic

A2W heat pumps can be mounted on concrete pads on the ground but, in deep-snow climates, they should be mounted higher than the anticipated snow level.

Freeze Protection

When a monobloc-style A2W heat pump is used in a cold climate, most manufacturers mandate the use of an antifreeze solution to prevent the heat pump from freezing when it's off. The most commonly used antifreeze is a 25% to 40% solution of propylene glycol.

Although it's possible to separate the antifreeze solution in the heat pump from water in the remainder of the system, this approach requires a stainless steel heat exchanger and an extra circulator, as well as more piping and wiring. It also adds a "temperature penalty" to the system. During heating mode, the heat pump must operate at a higher temperature than the water in the remainder of the system. This is necessary to force heat across the heat exchanger at a suitable rate. The simplest, lower cost, and higher performance solution is to use antifreeze solution throughout the system.

Comparing Heat Pumps

It's common for efficiency-minded consumers to select a heat pump based mostly on the highest COP. If the costs over the lifetimes of all of the heat pumps were the same, this would make sense. But because these technologies are largely climate-responsive and performance varies depending on several variables, comparing heat pumps using only COP can be misleading.

In cold climates, the greatest energy consumption is for space heating. To compare the heating energy cost of one heat pump to another, the seasonal energy savings associated with the higher-performing heat pump can be estimated using the following formula.

S = Load × [(1 ÷ COP_L) - (1 ÷ COP_H)]

Where:

S = Savings in seasonal heating energy per 1,000,000 Btu (MMBtu)

Load = Total annual heating energy required for the building per MMBtu

COP_L = Seasonal average COP of heat pump having the lower of the two COPs

COP_H = Seasonal average COP of heat pump having the higher of the two COPs

The math shows that for any two heat pump systems being compared, the savings are directly proportional to the seasonal energy required to heat the building. The lower the building's heating load, the lower the savings.

An example house has a heating load of 36,000 Btu per hour when the outdoor temperature is 0ºF, and the desired indoor temperature is 70ºF. The house is located in Syracuse, New York, which has 6,720 annual heating degree days. The estimated annual space heating energy use is 49.7 MMBtu. One heat pump has a seasonal average COP of 3.28. The other heat pump has a seasonal COP of 2.8.

S = 49.7 × [(1 ÷ 2.8) - (1 ÷ 3.28)] = 2.6 MMBtu/year

The cost savings associated with an energy savings of 2.6 MMBtu per year depends on the cost of electricity. For example, if electricity sells at a flat rate of $0.13 per kWh, the cost savings would be $99 per year. Here are the estimated annual heating cost savings for the first heating season. If utility rates increase, so will the savings.

Cost Savings = 2.6 MMBtu/year × 292.997 kWh/MMBtu × $0.13/kWh = $99/year

It's now a matter of determining if the estimated total energy savings over the life of the systems can amortize the higher cost of the heat-pump system with the highest seasonal average COP. In my experience, the life-cycle cost of a well-designed A2W heat pump system can be lower than that of a geothermal heat pump, for example, assuming both are combined with the same hydronic distribution system. (Note that geothermal heat pumps are another option that can be connected directly to a hydronic heating system.) This is especially likely when both heat pumps are used in houses with low design heating loads (perhaps 15,000 to 30,000 Btu/hr.), and when the seasonal average COP of the A2W heat pump is perhaps 1.0 or less below than that of the geothermal heat pump (e.g., air-to-water heat pump seasonal COP = 2.5, geothermal water-to-water heat pump COP = 3.5).

The current 30% federal income tax credit on geothermal heat pumps (with no corresponding subsidy on A2W heat pumps) skews the life-cycle cost comparison. But even without subsidies, A2W heat pumps can be very competitive with geothermal systems. The most significant installation cost advantage is that A2W heat pumps don't require an earth loop, or a high-yield drilled well for their source energy.

Radiant ceiling panels—$^{1}/_{2}$-inch PEX-AL-PEX tubing spaced 8 inches apart with aluminum heat transfer plates—prior to drywall installation.

A radiant wall panel, also with PEX-AL-PEX on aluminum heat-transfer plates, installed behind drywall.

Major Components

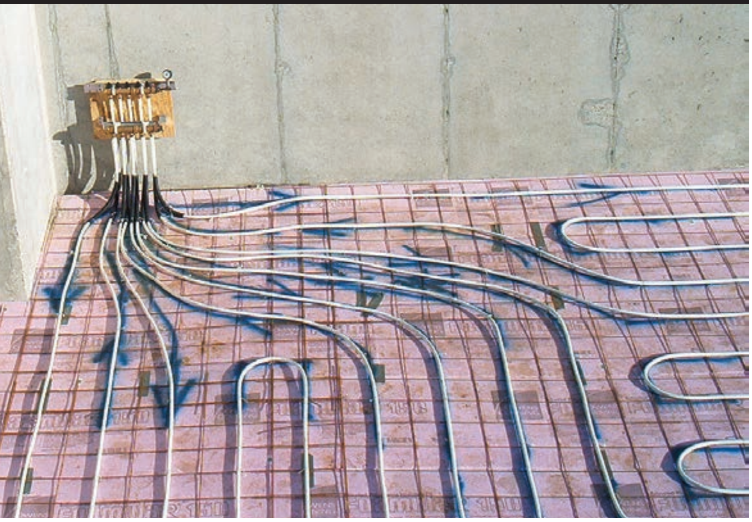
Heat emitters

To achieve the best heating performance, A2W heat pumps need to be combined with hydronic heat emitters that operate at low fluid temperatures. Specific types of radiant panel heating, which includes radiant floor heating as well as radiant wall or radiant ceiling heating, can work well with A2W heat pumps. Some can provide adequate heating at supply water temperatures lower than 100ºF, even on very cold days.

Radiant tubing embedded in concrete

One of the best options is a heated, 4- to 6-inch-thick slab-on-grade concrete floor with no covering (other than a coat of stain). In well-insulated buildings, and using close (6- to 12-inch) tube spacing and adequate edge and underslab insulation (R-10, minimum), heated slabs can maintain excellent interior comfort using water temperatures of 95°F to 105°F, even when outdoor temperatures are below 0ºF. Heated slabs covered by ceramic or vinyl tile can also be good performers. For optimum performance, avoid carpet, cork, or wood flooring over heated slabs.

The tubing is attached to welded wire reinforcing that's placed at half the slab's depth. This allows lower water temperature than systems where the tubing is placed at the bottom of the slab. When the required upward heat flow from a bare slab needs to be 15 Btu/hr./ft.^{2} (a typical design load condition for a well-insulated home) and the tubing is spaced 12 inches apart and placed midslab, the required average fluid temperature in the floor circuits is about 95ºF. If tubing is placed at the bottom of the slab, the average fluid temperature needs to be higher—102ºF—with all other conditions being equal. That 7ºF higher temperature negatively affects the heat pump's COP and its heating capacity.



John Siegenthaler (4)

Left: This layout for a heated slab consists of $^{1}/_{2}$-inch PEX-AL-PEX tubing fastened to welded wire reinforcing on top of extruded polystyrene insulation. Tubing and reinforcing will be lifted to mid-slab height when concrete is poured.

Below: A typical manifold station that supplies water to radiant floor-panel zones.

Other emitters

Other options include radiant tubing and aluminum heat spreader plates installed above or below wood subfloors, as well as radiant ceiling and wall panels. The useful heat output of these panels varies based on the average water temperature in the tubing.

The rated heat output of panel radiators is typically based on an average fluid temperature as high as 180ºF. A given panel's heat output at a lower average fluid temperature, such as 110ºF, is typically 20% to 30% of its output at 180ºF. In standard buildings, this usually translates into using larger radiators to meet the heating load. Panel radiators can be smaller in buildings with lower heating loads.

Thermal storage

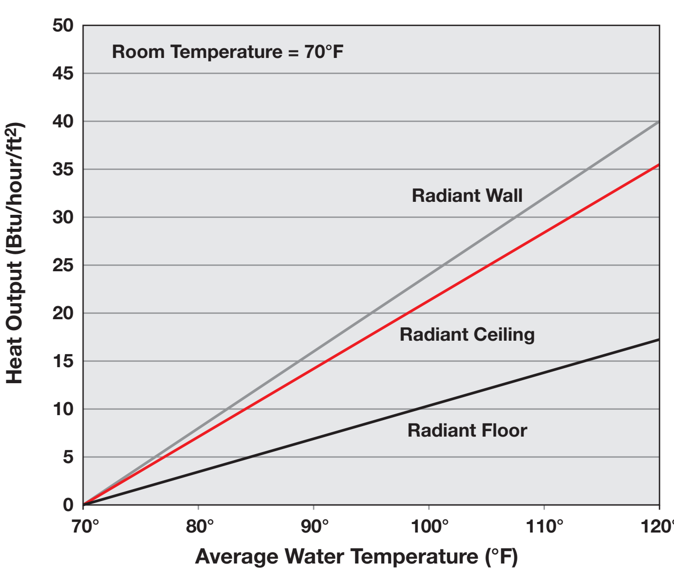
A2W heat pumps supplying zoned systems often operate at heating outputs higher than required when only one or two zones need heat. In this case, a buffer tank must be used between the heat pump and the remainder of the system. The thermal mass of the tank absorbs excess heat output from the heat pump, which reduces short cycling. After the heat pump shuts off, active zones draw stored heat from the buffer tank, which allows the heat pump to remain off, often for several minutes. Fewer and longer heat-pump operating cycles decrease wear on heat pump electrics, lengthening its service life.

John Siegenthaler (2)

A typical wall-panel radiator with wireless thermostat. Although their origins are in Europe, panel radiators are now readily available in North America.

The greater the buffer tank's volume, the longer the heat pump's cycles. For most residential systems, buffer tanks between 40 and 119 gallons are sufficient. The smaller tanks are appropriate for A2W heat pumps with variable-speed compressors. Variable-speed compressors on some A2W heat pumps help match the heat pump's output to the load. This

Heat Output of Radiant Panels

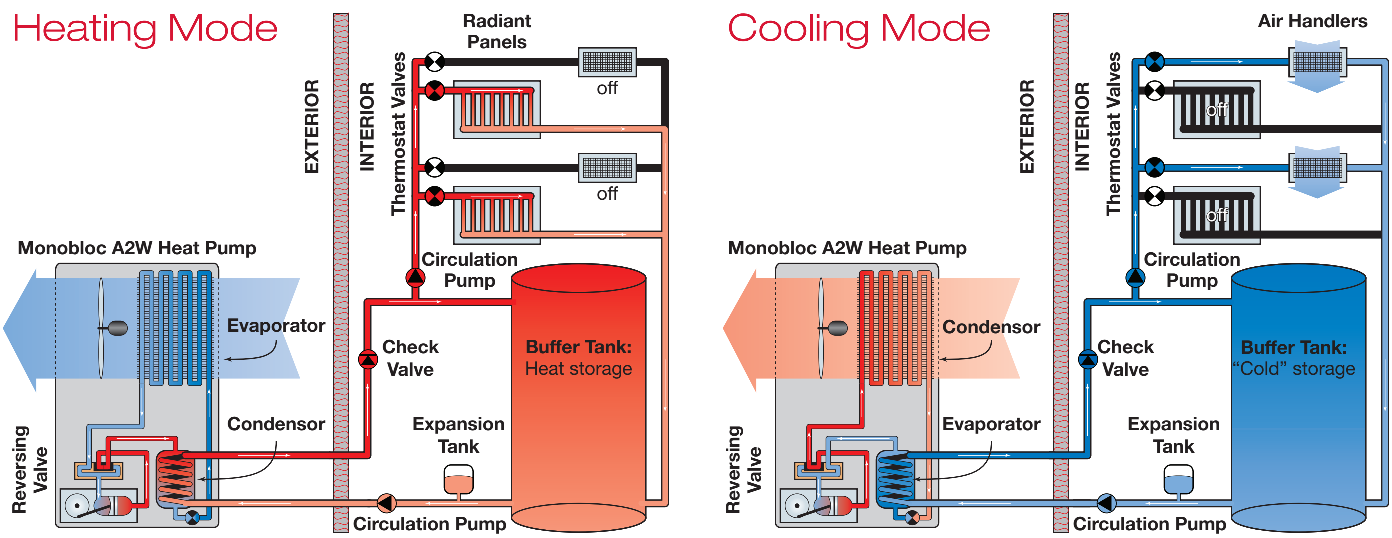


The useful heat output of each radiant panel is shown above. For example, the radiant ceiling panel releases about 22 Btu/hr./ft.^{2} into a 70ºF room below when operated at an average water temperature of 100ºF. Under the same conditions, the radiant wall panel releases about 24 Btu/hr./ft.^{2}, and the radiant floor panel—tubing spaced 8 inches apart on aluminum heat-transfer plates, installed below subfloor with an R-1 covering—releases about 10 Btu/hr./ft.^{2} The total heat output of the panel is determined by taking the Btu/hr./ft.^{2} output and multiplying by the panel's total area.

Courtesy SpacePak

Right: For most residential systems, buffer tanks between 40 and 119 gallons are appropriate.

A2W System Configurations



This monobloc-style A2W heat pump would typically be piped to a buffer tank. The hottest fluid coming from the heat pump enters a tee in the upper tank header. If the heating load is active while the heat pump is running, some of the flow goes directly to the load without first passing through the tank. This expedites heat delivery without having to first warm the tank. The remaining flow passes into the tank. Configuring piping so that flow enters the tank horizontally reduces internal mixing, and encourages desirable temperature stratification within the tank. Flow returning from the load passes through the lower portion of the tank. This provides interaction with the tank's thermal mass, and stabilizes system operation.

John Siegenthaler (2)

Using pressure-rated hose connections between the heat pump and rigid piping will accommodate thermal expansion and reduce vibration transfer.

Piping through exterior walls should be protected from condensation and insulated. Here, tubing from the heat pump passes through a 2-inch PVC sleeve; the space between is filled with expanding foam insulation.

is desirable when the heating or cooling distribution system is divided into several zones. A larger buffer tank is generally needed for on/off heat pumps. Buffer tanks are available from several companies, such as Caleffi, Flexcon, and Thermo 2000 (TurboMax).

Zoned System Example

The system shown in the schematic above uses an A2W heat pump to supply two independently controlled zones of radiant panel heating and two systems of air-handler cooling. The entire hydronic system is filled with a solution of 30% propylene glycol.

Heating mode

When a zone calls for heat, the associated zone valve opens and the circulator pump turns on. The speed of the circulator automatically adjusts depending on which zone(s) are operating. If zones operate simultaneously, the circulator's speed automatically increases. Any flow not sent to the distribution system passes into the buffer tank.

The heat pump is turned on and off based on the temperature at the midpoint of the buffer tank. That temperature varies based on outdoor temperature. The colder it is outside, the warmer solution the heat pump sends to the tank. When a zone calls for heat, the heat pump runs until the temperature sensor reaches a target that is continuously adjusted by an outdoor reset controller. This controller helps keep the system operating at the lowest temperature that can maintain comfort in the building, maximizing the heat pump's COP.

Cooling mode

Cooling and dehumidification are provided by passing chilled fluid from the buffer tank through independently controlled air handlers. The chilled fluid passes through copper tubing in the air handler's coil as room air is pulled through the coil by a blower, and is then distributed to rooms, directly or through ducts. Water droplets that form on the coil as the air is dehumidified fall into a drip pan and are drained away.

All piping and components carrying chilled fluid must be insulated and vapor-sealed to prevent condensation. This is a critical detail that is often overlooked or poorly done. The result will be water puddles and stained surfaces under the piping and the components carrying chilled fluid.

Resources

A2W Heat-Pump Suppliers

Aermec • aermec.com

Chilltrix • chilltrix.com

Maritime Geothermal • nordicghp.com

SpacePak • spacepak.com

ThermAtlantic Energy Products • thermatlantic.com

Further Reading

"Renewable Hydronic Heating" by John Siegenthaler in *HP152* • **homepower.com/152.50**

Modern Hydronic Heating, 3rd edition by J. Siegenthaler, Cengage Learning, 2012.

Heating with Renewable Energy by J .Siegenthaler, Cengage Learning, 2017.

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PV Circuit Calculations

by Ryan Mayfield

For PV circuit calculations, just reading through the *National Electrical Code (NEC)* requirements can be difficult and frustrating. Getting familiar with these figures by reviewing concrete examples can make the rules easier to follow. This example, which uses the electrical specifications below, takes you through Section 690.8 circuit-sizing requirements for a typical residential or small commercial installation and shows where all of the different calculations are applied.

PV Module

- Pmp = 340 W
- Voc = 48.0 VDC
- Vmp = 38.2 VDC
- Isc = 9.53 A
- Imp = 8.9 A

Inverter

- Maximum power = 7,600 W
- Continuous output current = 32 A

DC Optimizer

- Maximum output current = 15 A

The example location is Denver, Colorado, where the ASHRAE 2% high temperature is 34°C. The Solar ABCs map data (bit.ly/SolarabcMap) shows two high temperatures. The 0.4% temperature is the air temperature that is exceeded for three hours (not necessarily continuous) in a summer month, June through August. The 2% number represents the temperature exceeded for 14 hours and is the value recommended for use in the calculations.

690.8(A) Calculations

690.8(A)(1)(1)—The maximum source-circuit current for a single series string of PV modules:

Isc × 1.25 = Maximum circuit current
9.53 × 1.25 = 11.91 A

690.8(A)(1)(2)—Doesn't apply to this example because of the system's size.

690.8(A)(2)—The maximum output current for the series strings placed in parallel. This is relatively uncommon in modern systems due to the inverter MPPT configurations and the integrated DC combiners on larger inverters. For the sake of the example, let's say three strings are placed in parallel and we need to calculate the output current of the combiner:

3 × Single String Imax = Total maximum circuit current
3 × 11.91 = 35.73

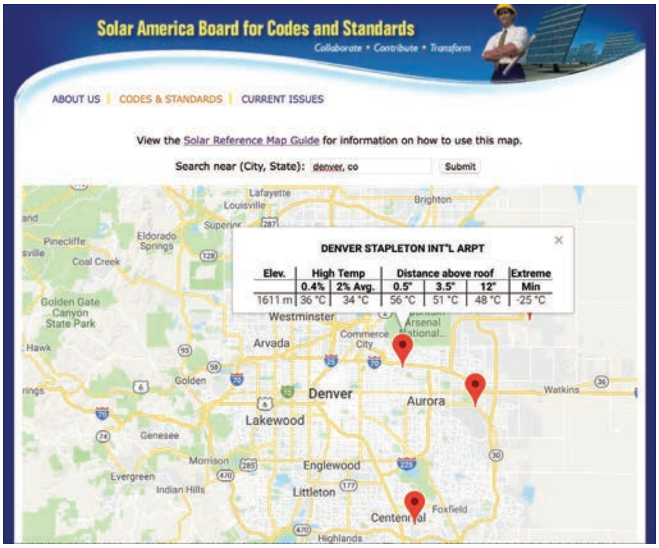
690.8(A)(3)—The maximum inverter output circuit current is the listed value from the manufacturer: **32 A (no correction factor need be applied)**.

690.8(A)(4)—The output current for a stand-alone inverter. This is a grid-tied inverter, so this section does not apply.

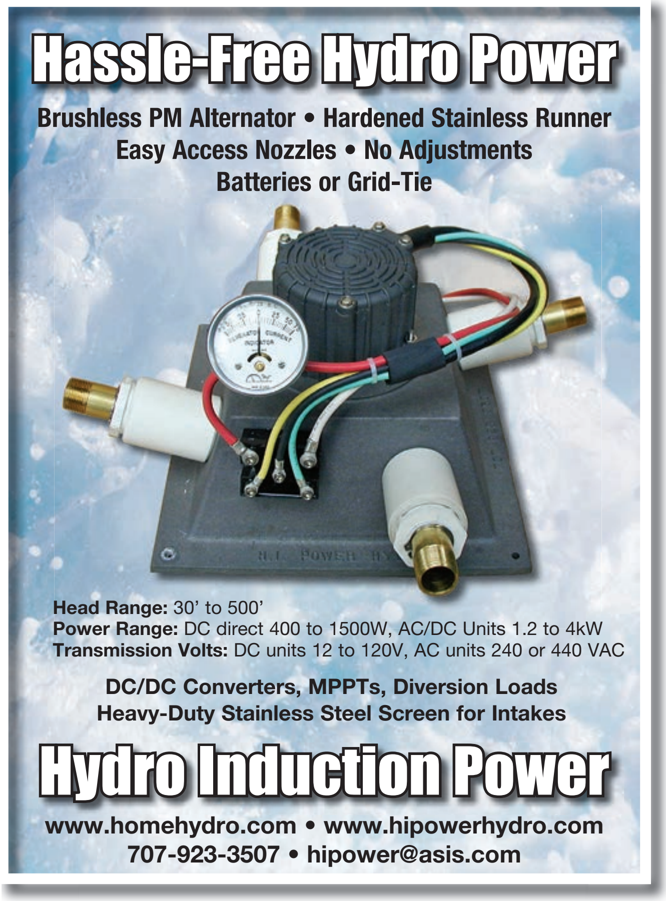
690.8(A)(5)—The maximum current for the output of a DC-to-DC converter source circuit: **15 A**.

continued on page 50

Solar ABCs Temperature Data



Courtesy solarabcs.org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NEC Table 310.15(B)(16)

310.60 ARTICLE 310 — CONDUCTORS FOR GENERAL WIRING

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

	Temperature Rating of Conductor [See Table 310.104(A).]						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0

continued from page 48

690.8(A)(6)—The output circuit current for DC-to-DC converters placed in parallel. If there were three DC-to-DC source circuits placed in parallel prior to the inverter connection:

15 A × 3 = 45 A

690.8(B) & Conductor Ampacity

Next is the application of 690.8(B) and calculating the required conductor ampacity. For our example, the circuits run in a raceway two inches above the roof's surface, then down to an inverter at ground level. For the noncombined applications, we will consider three source circuits running all the way to the inverter's MPPT input.

690.8(B)(1)—For a situation in which no DC-to-DC converter is used, and the source circuits run all the way to the inverter:

11.91 (total max. circuit current) × 1.25 = 14.89 A

Based on the 75°C column for copper-only conductors in Table 310.15(B)(16)—a portion of which is shown above—14 AWG (minimum) is specified. The 75°C column is used when all the terminals used for the conductors in this circuit have that temperature rating, which is common for equipment listed for PV applications. We use this 75°C rating because the terminals are the limiting factor for the ampacity.

690.8(B)(2)—Conditions are six current-carrying conductors and an ambient temperature of 34°C. Table 310.15(B)(3)(a) requires an 80% correction factor for the number of current-carrying conductors in a raceway. Table 310.15(B)(2)(a) has a 0.96 correction factor for conductors rated at 90°C, such as THWN-2. [For circuits located in raceways less than 7/8 inches from a rooftop or for those still operating in a *Code* cycle before 2017, the ambient temperature used must be added to an additional correction factor per 310.15(B)(3)(c).] Here, the 90°C column can be used, since the ampacity of the conductor, not the terminals, is being evaluated.

Using the same 14 AWG conductor with 25 A ampacity in Table 310.15(B)(16):

25 A × 0.8 × 0.96 = 19.2 A

Because 19.2 A is greater than 11.91 A [the maximum current calculated in 690.8(A)(1)(1)], we know that this conductor is sized properly.

The final step is to compare the conductor's ampacity to the overcurrent device required per 690.9. In the scenario presented without DC-to-DC converters, a 15 A OCPD can be used to protect these circuits and a 14 AWG conductor would be acceptable. *NEC* Section 240.4(D) applies to matching OCPDs to conductors. This section requires that smaller conductors—14, 12, and 10 AWG copper conductors—be protected by OCPDs that do not exceed 15, 20, and 30 A, respectively. Therefore, if you calculate that a 20 A OCPD is needed, 12 AWG conductors need to be used.

This same process is used on all the other circuits to calculate the minimum conductor sizes. The key is to evaluate the different requirements individually—too often, designers skip steps, applying factors and calculations incorrectly.

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18. I certify that the statements made by me above are true and complete. Joe Schwartz, Publisher, 10/01/18.

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Conflagration & Salvation

by Kathleen Jarschke-Schultze

There's an old saying that goes something like: "You make plans; the gods laugh." As you may remember from my previous "Home & Heart" (*HP187*), I was looking forward to Bob-O and my annual work/play gig at Oregon Country Fair (OCF). There, our job is to set up PV systems for four performance stages, and battery-charging stations for various food booths. We were leaving our house, gardens, and dog in the hands of a young couple eager to experience off-grid living for a short time. But none of that happened this year. What did happen was the Klamathon wildfire.

Ignition

Thursday, July 5th, 1:31 p.m. Bob-O had gone to our nearest city—about an hour's drive north, in southernmost Oregon—to pick up the batteries we needed for the OCF power systems. About 30 minutes from home, while driving through Hornbrook, California, he spotted a wildfire. Although it was near town, it was also across the Klamath River, a fairly wide expanse of water. He stopped, took a picture, and texted it to me. Around here, any wildfire is of interest, especially if it is relatively close to your house. He told me that firefighters were using water tankers, two helicopters with buckets, and a borate plane to try to quell the flames. As dry and hot as our weather had been, they were throwing every resource they could on the fire to keep it from spreading.

We checked local social media often that afternoon and evening to get real-time updates on the now-named Klamathon Fire. By 3:15 that afternoon, the fire had jumped the Klamath River and the entire town of Hornbrook was being evacuated. It had grown to 50 acres and was 0% contained.

Less than an hour later, Interstate 5 was closed to any but emergency vehicles. Driven by strong winds, the fire had jumped the four lanes of the freeway. By 5 p.m., the fire had grown to 500 acres; by 6 p.m., it had consumed 1,000 acres.

If Bob-O hadn't departed when he did, he would have been stuck in Oregon. That happened to a friend, who had to wait at her daughter's house in southernmost Oregon, as the area near her ranch was burning. That morning, she had left four dogs, 30 goats, a llama, and assorted chickens, expecting to return soon.

Evacuation

Friday morning, after little sleep, we continued preparing for our trip to OCF. We were hoping the fire would be contained before we had to leave on Sunday. I packed my car with camping gear, clothes, and my camp kitchen that I use to feed our crew of 10. We checked fire updates often and activated the CodeRED Mobile Alert app on our phones.

Throughout the day, we monitored the fire's unbridled spread to the north and east of Hornbrook. Multiple homes had burned, one firefighter was injured, and one Hornbrook man had died. The town of Hilt, to the north and close to the Oregon border, was under mandatory evacuation orders.

We could see smoke in the western sky as the fire burned its way toward us. I circled the house, moving any combustible materials to a pile on a bare patch of dirt that was well away from any structures. In the carport, under our deck, I left a set of wooden double doors leaning against the house wall—they were just too heavy for me to move alone. Bob-O was busy, too, moving our tractors and backhoe out into the mown field, away from any buildings.

I took my old iPhone and video-recorded every room in our house, plus the shop, the PV arrays, my chicken coop and greenhouse—everything I could think of. All the while, I was thinking, "What if this is the last time I see this life we built?"

We roamed the house, taking down pictures and paintings, and placing them in the Keep—a 20-foot-long earth-sheltered steel container. All of our musical instruments, computers, hard drives, and important papers followed. I stuffed our house insurance file behind the seat of my car. I turned on our indoor house security cameras.

3:42 p.m. I stood at our back door and took a picture of the ever-advancing black plume of smoke visible to the east of our small canyon.

4:31 p.m. We both received reverse 9-1-1 calls from our local sheriff's office—a recorded message telling us to evacuate. Although my car, Suby (a Subaru), was already pretty packed, I squeezed in all of the dog's travel gear, food, and bed.

We hooked up our 19-foot-long travel trailer to our pickup, towed it to the nearby campground, and parked it in the middle of the largest area of bare dirt we could find. Mike, a member of our OCF crew, hitched a ride to our house to help Bob-O load our truck and a small, enclosed trailer with all of the equipment needed to build the PV systems used at the OCF. He would drive the truck and trailer to OCF without us. Literally thousands of people were counting on us to do our jobs there. For the first time in 23 years, our crew would have to carry on without us.

While Bob-O and Mike packed equipment, I left with the dog for our friend Myna's house, on the south side of the Klamath River, where we would stay. A policeman was stationed at the end of our dirt road to keep anyone from returning once they had left. But to my surprise, when I arrived at Myna's house, she and her husband Dave were packing up their car and hooking up their travel trailer to their truck. They had just received their evacuation orders and would be leaving within minutes. I drove on to an evacuation center—an elementary school in Yreka.

10 p.m. Bob-O joined me at the school. He was driving our old Outback station wagon, lovingly nicknamed the Skibaru. Before leaving, he set up two Rain Bird sprinklers, one on the house's roof to wet the west side of the house and the woodshed, and one on the deck, wetting the side of the house facing the creek. We were very glad for the 5,700 gallons of automatically solar-pumped water stored on the hill above us that was supplying those sprinklers.

Frustration

That night, we slept in the Skibaru on a hastily made bed from the camp bedding I could easily unpack. While we rested fitfully in the cramped car, Lucea, our 80-pound Airedale, slept across the front seats of Suby.

Saturday, 6:38 a.m. As soon as we awoke, I used my phone to check the house cameras. We still had a house. Bob-O texted our would-be housesitters and let them know what was happening. Bob-O tried to return to our house, but was stopped by the National Guard 12 miles from home. We decided to buy a lottery ticket. If we lost our house, we figured the $308 million jackpot would soothe the burn.

The wind had shifted that morning; the fire appeared to be burning back on itself. Firefighters hit the ridge between our home and the fast-moving fire front with numerous bulldozers to cut fire lines, trying to stop the fire's eastern progress. Official word was that it would be several days before we could return home, but no word on what we might find there.

Saturday, 7:58 p.m. We attended the daily fire meeting at the Yreka Community Hall. At the beginning of every meeting, the first thing they said was, "This is not the meeting where we tell you that you can go home." Our county had all kinds of help—ranging from other fire and police agencies to the National Guard. Each division reported, and the National Weather Service gave us the weather forecast. Then they answered a few questions from the audience. The best (and smartest) thing they did after the meeting was to answer specific questions that people had.

Bob-O went right for a guy in a sooty Nomex fire shirt and asked him about the dozer line on the ridge to the west of us. That incident chief had actually been on Camp Creek—the creek that borders our property—that day. He reported the dozer line was progressing. When Bob-O asked if they were doing house protection, he answered, "If you live on Camp Creek, there is a crew protecting your house." That made me tear up a little. I thought, maybe I'll sleep tonight.

We moved from the evacuation center to a private RV park in Yreka that was allowing people to tent-camp under the extraordinary circumstances. My friend Myna talked them into letting us camp underneath the PV array. The owners had no idea how appropriate that setting was for us.

We heard from our friend with the goat ranch. A mutual friend had hiked past the roadblocks to feed and water her animals. He was there as the fire surrounded her ranch. He fought alongside the fire crews to beat back the flames. With the help of some borate drops, water from the onsite pond, and the fact that her goats had eaten away all the ladder fuels, her ranch was saved. The crew even helped wash the borate off her PV array before they left.

Sunday, 7:47 a.m. I checked the house cam; we still had a house. Bob-O asked me to turn on the audio and we heard the "shhh, shhh, shhh, thump, thump, thump" of the Rain Bird shooting water against the side of the house. That meant the sprinklers were running 24 hours a day. We had assumed the water tanks would empty at night, and then fill during the day, when the sun came out and shone on the PV modules. This proved our water storage was enough to supply two Rain Birds and all three gardens' automatic watering systems, too.

Bob-O pointed out that if I could connect to the house cam, it also meant that our other building—on the opposite hillside—was still there. That building has a small PV system, which powers a repeater with line-of-sight to a wireless Internet transmitter on Bogus Mountain. A smaller repeater is pointed to our house. If the cameras worked, that meant both buildings were still standing.

Fire Family

Bob-O's son Allen has spent his entire career fighting wildfires for the United States Forest Service, and is currently the supervisor of a hotshot crew (HC). His crew was on their way to the Klamathon Fire when their truck broke down and they were called back. Allen had hiked and hunted these hills and canyons since he was a kid. He got a topographical map and marked water sources, rock ridges, and the paths bulldozers could take to build fire line. He put a circle around our house and labeled it "Dad's house."

He received a text from a buddy in an HC who was working in our canyon, reporting that "your dad's place had sprinklers going and looked well-defendable. We will be back out there in the morning." These two sentences made my heart sing.

At that night's informational meeting, we had to laugh when we were all told that before anyone would be able to return home after the fire crews left, the utility would have to restore electricity. He used our road as an example. He was unaware that there are no electrical lines into the canyon. We spent another night under the PV array, thankful our camping gear had been packed in my car.

Monday, 9:17 a.m. We weren't going to be allowed home yet, and resigned ourselves to another day of evacuation. Intermittent winds gusting up to 20 mph were the problem. I went to the post office in Yreka where all the evacuees' mail was being routed. In anticipation of OCF, I had put our mail on hold. I had to explain that our trip did not go as planned and I now wanted my mail.

7:26 p.m. There was good news and bad news at the info meeting. The good news was that our friends Dave and Myna got to go home. They quickly packed up their car, but left their travel trailer at the RV park for us to stay in. Dave told us he would fetch it tomorrow and then we could follow him and stay in their trailer at their place.

The bad news was that Camp Creek was now the fire's leading edge. Many crews, helicopters, and borate planes had worked on that fire edge all day. I accessed the house cam; the house was still there. Moving from the tent to the trailer was a real step up in accommodations, and by the next day, we would be closer to home. Home—a word that had gained in value emotionally and in reality the last few days.

Tuesday, 6:34 p.m. At that evening's fire meeting, we found out we could go home! By cutting a dozer fire line through our yard and our meadow and to the head of the canyon and back-firing from that line, the fire had been stopped on its eastern edge.

We were packed and ready to go. Traveling in our two Subaru Outbacks, we slowly made our way into the burned area, past where the roadblocks had been. So much of the landscape had burned. Small columns of smoke still rose from inside the burn.

8:34 p.m. A quarter of a mile from our house, we were stopped by a firefighter keeping an eye on an intersection of Yellow Dog Trail and Camp Creek. He did not know whether we could return home yet. At the bottom of the road, I had counted nine semis with flatbed trailers for hauling dozers. Farther up, they were still actively fighting the fire. They didn't want us to run over any hose lines while they were being used. After about 15 minutes, the guy got confirmation to let us pass.

There was a big dozer-sized hole in our fence that would have to be fixed. The back-burn came within inches of the new PV array. We immediately cleaned the gardens' water filters. Some plants looked pretty good; others were stressed. Myna had sent dinner home with us because she knew I wouldn't want to cook. We had ourselves a celebratory drink and toasted to PV power. Glinda, the Good Witch of the North, was right: There's no place like home.

This will be the last column that I write for Home Power. *Print media everywhere is going the way of the typewriter. For us and for all the folks who have been in the solar industry a long time, it is the end of an era. Richard and Karen Perez started this magazine with a dream that renewable energy could go mainstream in America. Due in no small part to their hard work and vision, Richard and Karen lived to see that dream come true. Bob-O and I are proud to have been a small part. Be well. Live long and prosper.*

Comment & Discuss this article @ homepower.com/188.56

Further Reading & One Last Kudo

With *Home Power* ending its long, successful run, our loyal readers may be looking for ways to fill the gaps. Here are some publications that I enjoy, many of which cover subjects you are familiar with as *Home Power* readers.

First and foremost is *ReNew* (renew.org.au), an Australian magazine produced quarterly by the Alternative Technology Association. *ReNew* reminds me much of the early years of *Home Power*—it has lots of off-grid, hands-on, and techie renewable energy info, and also covers cleaner transportation options and more sustainable homes. ATA also publishes *Sanctuary*, which focuses on eco-friendlier homes, green building products, and sustainable landscape design, including drought-resistance.

Solar Today (ases.org) is a quarterly magazine published by the nonprofit American Solar Energy Society. More industry-focused than *Home Power*, it provides information on solar businesses, as well as commercial and utility-scale systems, and RE research.

Home Energy (homeenergy.org) is a quarterly technical magazine published by a nonprofit with the same name. It's all about building energy performance, and serving up the science of home energy to the building professionals who need it.

Mother Earth News (motherearthnews.com) is one of the original back-to-the-land magazines that comes out six times per year. They cover everything from renewable energy to organic gardening to raising farm animals ethically.

Last but not least, *Home Power* wants to acknowledge the important work of the nonprofit Midwest Renewable Energy Association (MREA, midwestrenew.org). Founded in 1990, MREA began organizing when Richard Perez, *Home Power* founder, put out the call for regional energy fairs across the nation. The 30th Energy Fair—with more than 250 workshops and 200 exhibitors—will be held in Custer, Wisconsin, from June 21–23, 2019. Throughout the year, MREA also hosts many RE and energy-efficiency online and onsite trainings for homeowners and energy professionals alike, and continues its work advocating for RE policy.

—Michael Welch

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