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Main Features

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On the Cover

Eric Hansen of True South Solar fastens PV modules to a PV rack that includes a channel for keeping wiring tidy.
Photo: Shawn Schreiner

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In Back

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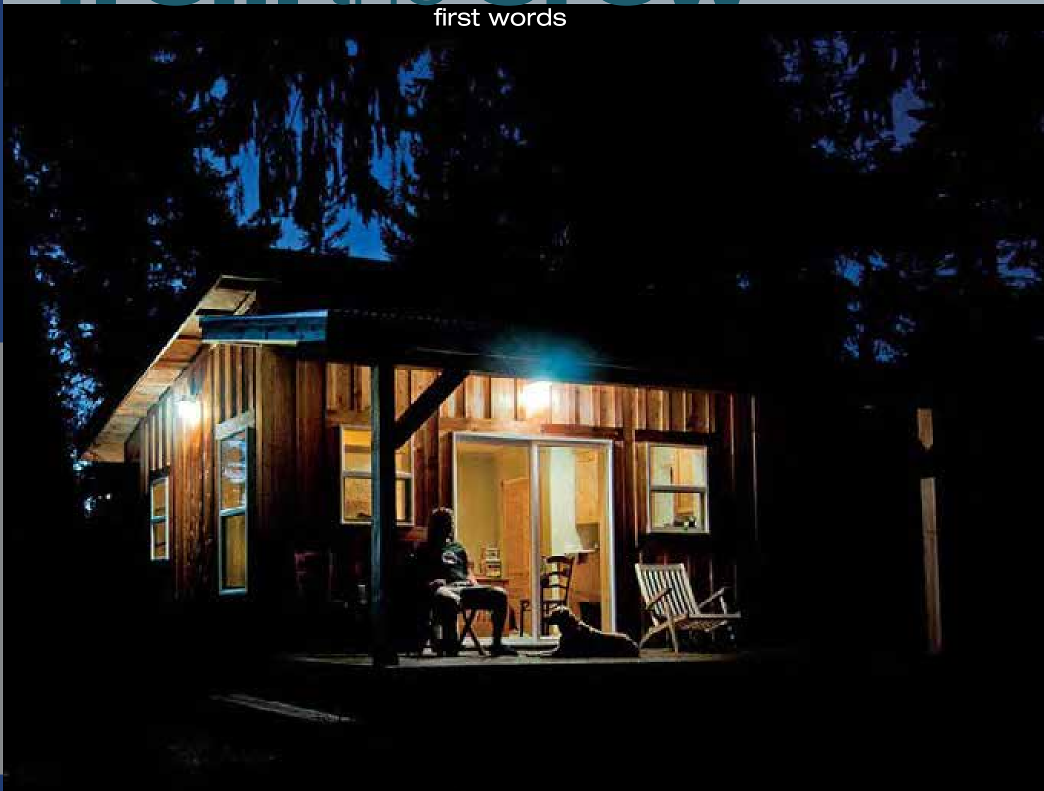

A Subtle Satisfaction

Shawn Schreiner

Gravel crunches under the tires and the truck's headlights lead the way across the steep hillside and onto the edge of the meadow. I shut the rig down, grab the groceries, and step into the starlight with my pup. Riffy darts back and forth, nose to the ground, excited to be back on the land.

We pad along the meandering path to the cabin. Two steps and we're up on the porch. Inside, I flip on the lights, drop the groceries on the counter, and grab a cold pale ale from the fridge. Its motor whirs up to a hum from my intrusion. Glancing at the energy monitor, I see that the batteries are full up—at 51.2 volts. I make my way to the stereo and spin up some Joe Strummer.

Riffy and I head back out, onto the porch. He hops off the edge to check on who has passed by since we've last been up—deer and coyote for sure, but how about bear, and maybe elk? I follow him out into the meadow and happen to glance back at the glow from the cabin. That's when it hits me.

I've been working in the solar biz for 15 years, and have had my off-grid place for coming up on 10. Even so, I still frequently experience a subtle feeling of surprise—and satisfaction—when I think about things running on sunshine. Solar energy is quiet. It's low-impact. It's reliable. It's a technology that never ceases to amaze, no matter how, or how long, you live with it.

—Joe Schwartz for the *Home Power* crew

Think About It...

I'm waiting for the rays of the morning sun;
somebody tell me clearly, has the new world begun?

—Joe Strummer

contact us

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Reviving PACE

Removing RE & EE Barriers

Imagine a government program that improves home values, reduces home ownership costs, saves energy, creates jobs, increases tax revenues without increasing taxes, requires no government subsidies, and leverages private capital for social good.

No need to imagine, that's the Property Assessed Clean Energy (PACE) program, which is now authorized by 28 states and the District of Columbia as of August 2012. PACE removes two barriers to improving energy efficiency and installing renewable energy systems in homes—high upfront costs and the fear of recovering those costs before the property's sale. Implementation of PACE for residential properties ground to a halt when the federal government, which owns most home mortgages in the country, objected to a PACE lien being in first position for payment in the case of mortgage default.

Here's how PACE works: A state or local government establishes, in statute or other policy, that the public purpose of a PACE program (clean and renewable energy, jobs, better air quality, etc.) is valid. Then a real-property secured-benefit district is formed (if it's not an entire municipality already). District property owners may participate or not; those who do not participate won't see their taxes or assessment change as a result.

To participate, an energy audit is usually required to determine the cost-effective measures to be performed by a qualified contractor. Financing is provided by the special district, typically by selling bonds that are secured solely by the payments received from participating property owners. General taxpayers are not on the hook in any way. Property owners who benefit pay off the costs for up to 20 years as part of their regular tax bills. Typically, PACE financing won't exceed 10% of the property's value; only properties with positive equity are eligible, and the program is available only to property owners who have a good tax payment record. There also must be no involuntary liens (PACE is a voluntary lien) on the property.

Because the ongoing cash savings to property owners exceed the added PACE assessment on the property, repayment is easy. The obligation transfers to the new owner if the property is sold. If the property goes into default, the bondholders are protected, since the government assessment of "taxes" is not a loan—it is first in line for repayment when the property is sold.

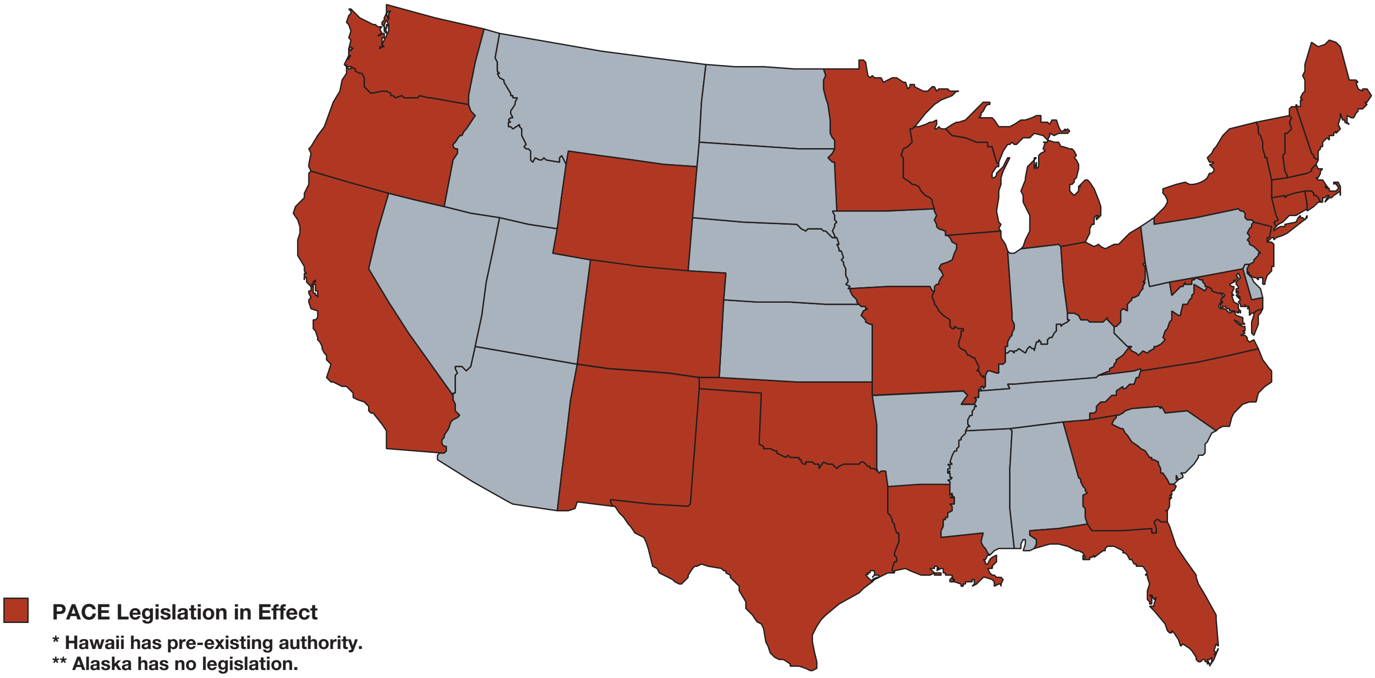
In 2008, PACE began as pilot programs in California, and was replicated in 23 states in just two years. Then, just as implementation was beginning, the residential programs came to a screeching halt in the spring of 2010 when the Federal Housing Finance Agency (FHFA) and the Office of the Comptroller of the Currency (OCC) said that PACE "presents significant safety and soundness concerns to the housing finance industry." As the housing finance industry was already significantly unsafe and unsound due to lenders making loans on homes with highly inflated values, the two federal agencies were concerned about making things worse. The FHFA regulates Fannie Mae (Federal National Mortgage Association) and Freddie Mac (Federal Home Loan Mortgage Corporation), which hold $5 trillion in mortgages. Fannie and Freddie are "government-sponsored enterprises," Congressionally chartered corporations that the government bails out when they get into financial straits. Fannie and Freddie defaulted in 2008, so the FHFA now also serves as their conservator, as well as regulator.

"Typically, the tax liens created by assessments are senior to other obligations, like mortgages, and must be paid first in the event of foreclosure," notes the Lawrence Berkeley National Laboratory in the "Clean Energy Financing Policy" 2010 brief. "Fannie Mae, Freddie Mac, the FHFA and other financial regulators reasoned that PACE assessments were, in effect, loans—not assessments—and as such violated standard mortgage provisions requiring priority over any other loan."

But many in the renewable energy, affordable housing, real estate, environmental, local government, and venture capital sectors think that Fannie and Freddie's concerns are misplaced—PACE tends to self-select responsible and stable property owners, and the default rate on PACE properties is 0.1%, while the national average for mortgage default is more than 30 times that (3.2%). No matter, though, for PACE is still stalled out until federal regulators change their minds.

Perhaps the courts will free PACE. PACE advocates won a case in the Northern California U.S. District Court that required the FHFA to undertake a formal "rule-making" exercise. The court also required the preparation of an environmental impact statement (EIS) evaluating the consequences of the federal government's change in policy. Sometimes, the open process of an EIS results in government making a better decision.

States with PACE-Enabling Laws



The FHFA appealed the ruling to the U.S. Ninth Circuit Court of Appeals, which allowed the FHFA to postpone implementing a final rule. If the FHFA wins on appeal, the rule-making process will likely stop, unless the FHFA changes its decision or has it changed by the White House. On June 15, 2012, the FHFA issued a proposed rule that would have the effect of killing residential PACE programs.

Perhaps Congress will free PACE. The PACE Protection Act of 2011 (HR 2599, 112th Congress) has 54 cosponsors from 15 states. It would:

- Rescind the FHFA, OCC, Fannie and Freddie 2010 guidance.
- Prohibit discrimination against PACE homeowners and communities.
- Declare that PACE is an assessment, not a loan.
- Limit any risk to Fannie and Freddie by requiring national program standards, underwriting criteria, consumer protections, and qualifying improvements and contractors.

The legislation would define PACE activities to include water and energy efficiency and renewable energy retrofits of most kinds. There have not yet been hearings on the bill in the House of Representatives, and no companion legislation has been introduced in the Senate.

Perhaps the White House will free PACE. It could tell the FHFA to reverse its course. It is a jobs program in an election year, after all.

An ECONorthwest (tinyurl.com/HPPACEstudy) study commissioned by PACENow found that for every $1 million spent locally, $10 million in gross economic output; $1 million in combined federal, state, and local tax revenues; and 60 jobs result. And rather than *increasing* the risk of default, ECONorthwest found that PACE's lowering of energy operation costs and increasing of home values would *decrease* the risk of default.

While the Obama administration is supportive of PACE, the FHFA is an independent regulatory commission that is not directly answerable to the President, unlike most federal agencies. FHFA Administrator Ed DeMarco fears PACE will result in the federal taxpayers not getting as much money back for the Freddie Mac- and Fannie Mae-backed loans that are ultimately guaranteed by the federal government (aka "taxpayers"). As long as he's in office, residential PACE is likely dead. The best hope for residential PACE is either for Congress to enact a law that gives national blessing to the local programs or for the President to convince the Senate to confirm his appointee, neither of which is likely to happen until after the next election.

—Andy Kerr

on the web

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Toward Grid Parity

What will it take for PV-generated electricity to be price-competitive with traditional fossil-fuel based electricity?

In certain applications or with some financial incentives, PV electricity is at or near grid parity: when the solar electricity costs are equal to or lower than the residential retail electricity rate. However, to reach widespread grid parity, the cost of installing and operating PV systems still must be reduced to become competitive *without* subsidies.

PV-made electricity must compete against very cheap electricity from natural gas turbines. "When it gets to $1 a watt, solar will be the same cost as natural gas energy, without subsidy," said Department of Energy Secretary Steven Chu.

"Significant reductions are still required to make it a true 'game-changer,'" says the Rocky Mountain Institute (RMI), an energy-efficiency think tank, in its report "Achieving Low-Cost Solar PV." PV modules make up about half of a PV system's cost, and module prices have been falling rapidly (see "Plummeting PV Costs" in *HP148*). Significant cost reductions are also being seen with PV components, labor, and permits.

Among many aspects for PV electricity to reach parity, the *SunShot Vision Study* by the U.S. Department of Energy examines balance-of-system (BOS) costs. The study divides BOS cost-reducing strategies into two classes:

Hard. Better supply chains; high-voltage systems; improved mounting integration for modules and roofs; innovative materials; standardized/packaged system designs; and building-integrated PV.

Soft. Permit and interconnection streamlining; better software and databases; removing barriers (policy, regulatory, and utility); workforce development; creative financing approaches; development of best practices; and reducing supply chain margins, while increasing overall profits.

BOS costs are decreasing, but the SunShot Initiative seeks to push them much lower, and faster than market evolution would normally, by directing government research and development that supports cost-saving technologies and processes, encouraging standardized and streamlined permitting by local jurisdictions, etc. In 2013, BOS costs are forecast to decrease about $0.29 per watt from 2010 amounts, according to GTM Research, a market analysis firm.

In 2010, RMI reported that near-term cost reductions could approach 50% (or $0.60 to $0.90 per watt) below current best practices, and that such reductions are necessary to achieve the wide-scale application of PV systems. RMI identified that standardization and integration are key to lowering system costs. Here are a few of its recommendations:

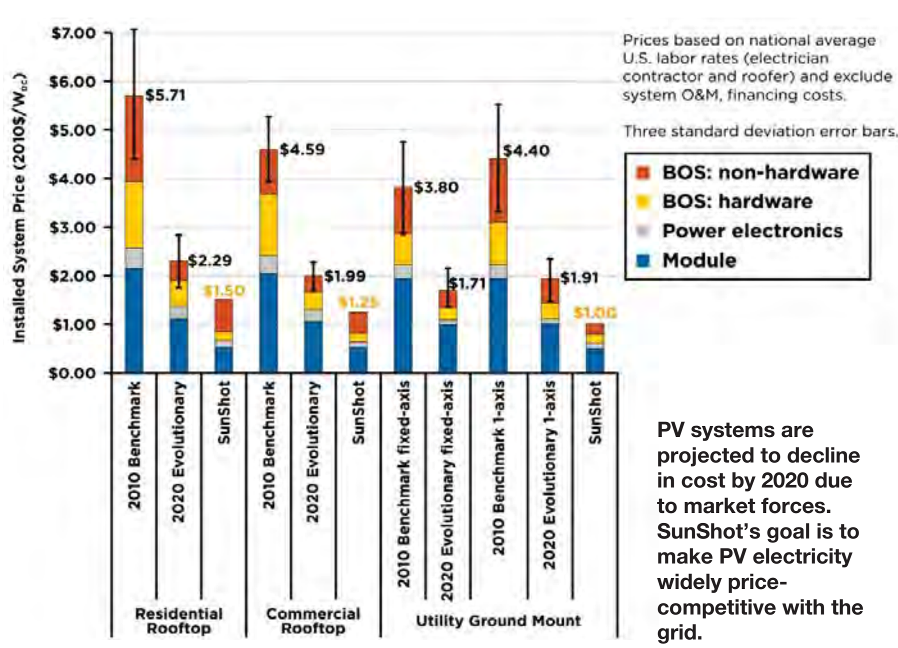
Standardize PV module physical dimensions. Nonstandard sizes mean higher rack and installation costs.

Integrate microinverters into PV modules. It's faster and cheaper to combine them at the time and place of manufacture than connect them during installation.

Rethink electrical system architectures. Higher voltages mean greater efficiencies and use of smaller, less expensive wire.

Design for, not against, the wind. A solid array at an optimum sun angle may have huge wind-loading stresses.

Installed PV System Prices: 2010 Benchmark, Projected 2020 Evolutionary, and 2020 SunShot Targe



PV systems are projected to decline in cost by 2020 due to market forces. SunShot's goal is to make PV electricity widely price-competitive with the grid.

Courtesy: US DOE; Source: Goodrich et al. (2012)

Reducing the module angle to minimize drag and leaving gaps between the modules to let the wind pass can significantly reduce engineering and rack requirements, reducing cost.

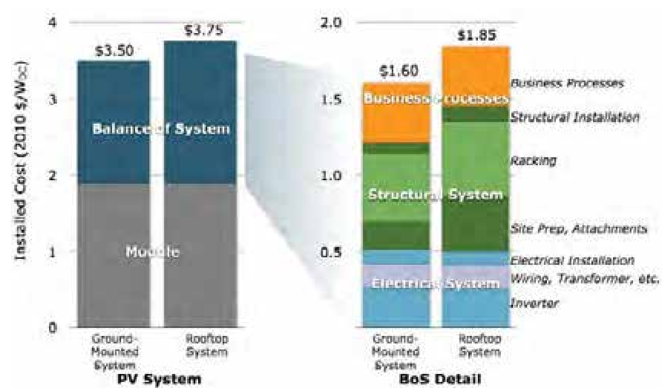
Streamline and simplify permits. With increased standardization of systems and components, local jurisdictions will be more willing to improve their permitting processes. Permitting costs are a large BOS component and can be dramatically reduced without compromising safety.

A report by Sunrun, a residential PV leasing company, found that local permit costs averaged $2,516 per residential installation (about $0.50 per watt). Sunrun argues for standardized, streamlined, and consistent permitting, while ensuring safety by meeting code requirements through the widespread adoption of policies recommended by Solar America Board for Costs and Standards, a project funded by the U.S. Department of Energy.

John Farrell of the Institute for Local Self-Reliance estimates that by achieving all of these BOS recommendations—and with just the federal tax credit—PV-generated electricity could be price-competitive with, or even less than, average retail electricity rates in 13 of the 20 largest U.S. metropolitan areas. With time-of-use metering (higher utility rates when demand is high—such as during hot summer days), PV-generated electricity could be less than the average grid electricity price in 19 of 20 metropolitan areas.

—Andy Kerr

Cost Breakdown of Conventional U.S. PV Systems ca. 2010



Courtesy: Rocky Mountain Institute

Not included in the above breakdown is the cost of the land upon which a ground-mounted system rests. Roofs are readily available, so the land cost of roof-mounted PV systems is effectively zero.

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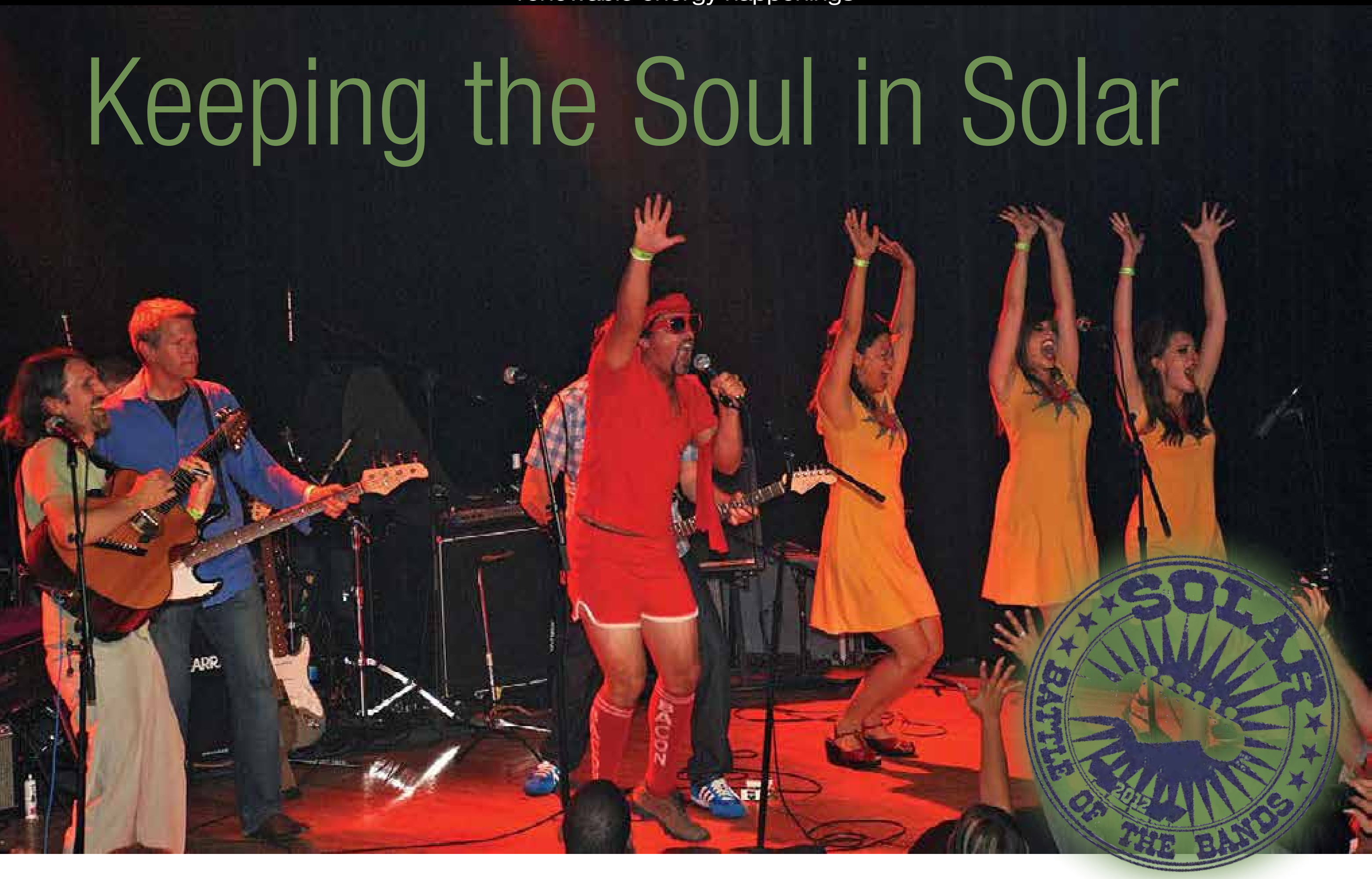
Keeping the Soul in Solar



Zep Solar: Zep, The Band

This summer, a few dozen solar professionals put down their usual tools of the trade, picked up instruments that included everything from electric guitars to trombones, and showed off a completely different talent—jamming out some good ol' rock and roll.

Quick Mount PV: Wave Array

All photos courtesy Solar Battle of the Bands

At the second annual Solar Battle of the Bands in San Francisco, five bands put on an entertaining (and loud!) show of musical prowess. The brainchild of Johan Alfsen, Quick Mount PV's training director (and also the bass player for the show's house band, Wave Array), the rock-and-roll rumble played to a crowd of more than 1,200 industry pros at an after-hours event held during the Intersolar North America conference. Quick Mount PV partnered with Session Solar to produce the festivities and sponsors included SCHOTT Solar, SMA America, Creotecc Solar Mounting Systems, Antenna, AET, Burndy, NABCEP, SunEarth, *Home Power*, *SolarPro*, Intersolar, and NorCal Solar.

The participating bands were required to be comprised entirely of employees from their respective companies. And that leads us to the immediate question, "Can a bunch of solar engineers, equipment manufacturers, salespeople, and system integrators make good music?" You bet they can.

Sungevity: The Killa Watts

SolarCity: The SoulMetrics

Session Solar's Christie McCarthy, backed by Wave Array, kicked off the evening with the performance of her solar anthem, "Rise and Shine." Tioga Energy got the contest—and the party—started with covers that included funked-out versions of Stevie Wonder's "Superstition" and Al Green's "Take Me to the River." Sungevity's Motown-infused set included Creedence Clearwater Revival's "Proud Mary," done in the finest Ike and Tina Turner style, with stellar vocals by Colleen George. Next up was SMA America's band, which featured the company's president, Jurgen Krehnke, at the helm and in full control of the mic. Zep Solar brought down the house with the B-52s classic, "Rock Lobster," complete with a trio of hair-piled-high backup singers; the company's chief technology officer, Jack West, on an eight-string guitar that he built; and vocals and fearless stage antics by Daniel East. SolarCity closed out the contest with tunes that included Janis Joplin's "Piece of My Heart" and a bouncy take on Dexys Midnight Runners' feel-good classic, "Come on Eileen."

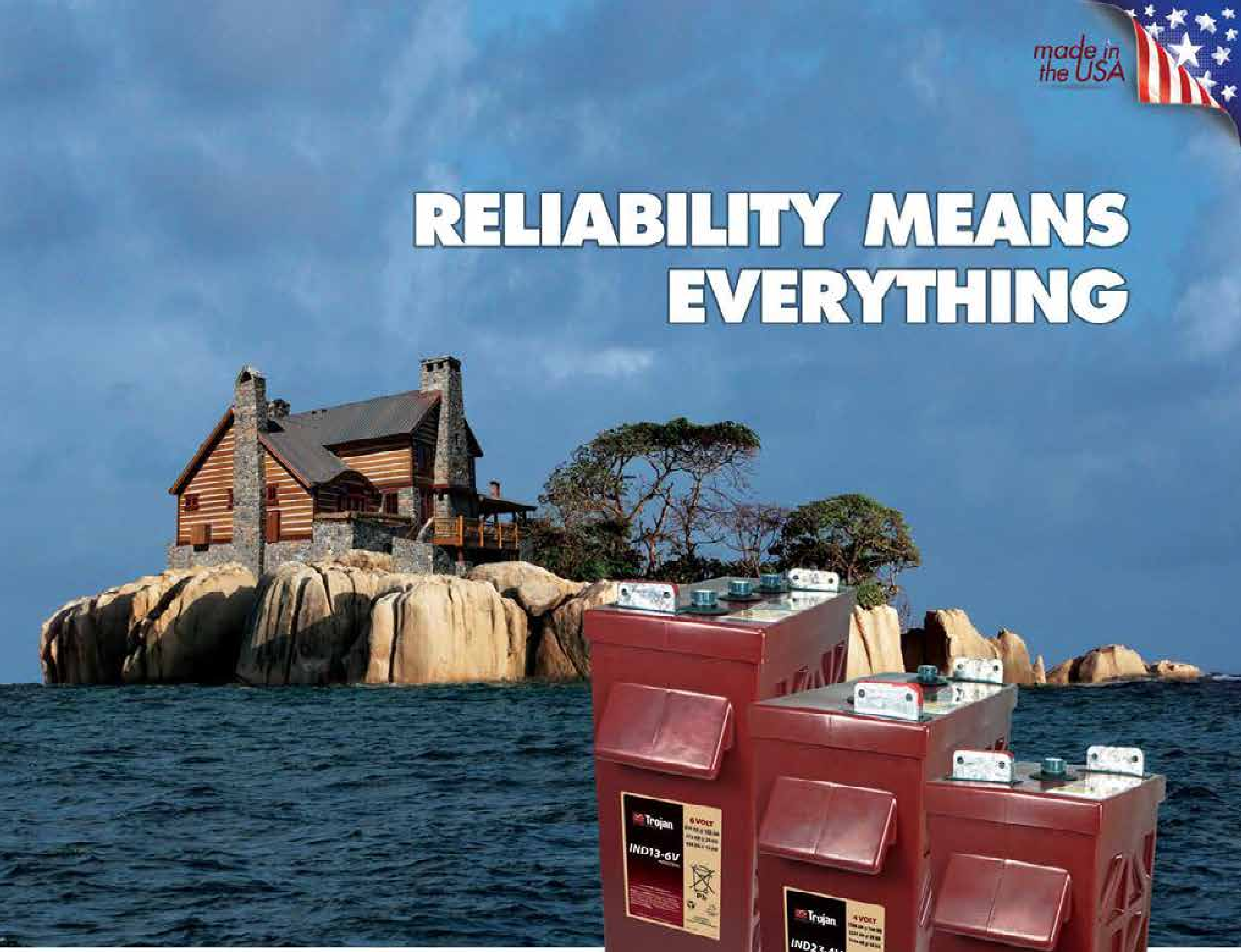
As Wave Array filled the venue with psychedelic guitar riffs, the crowd cast their votes and event organizers tallied the results: Zep Solar's Zep, The Band, came away with the win and Sungevity's The Killa Watts wrapped up the contest's second position. You can check out highlights from the show at: solarbattleofthebands.com.

At times, today's solar industry can feel a lot more serious than it did a decade ago, when major industry events were held in grassy fields rather than in air-conditioned indoor expo halls. The Solar Battle of the Bands was a refreshing and entertaining reminder that there are plenty of talented people who work hard—and play hard—to keep the soul in solar.

—Joe Schwartz

Tioga Energy: Special Purpose Entity

SMA America: The Voltaics



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IND23-4V	4 VOLT	977	1233	1500
IND29-4V	4 VOLT	1245	1570	1910
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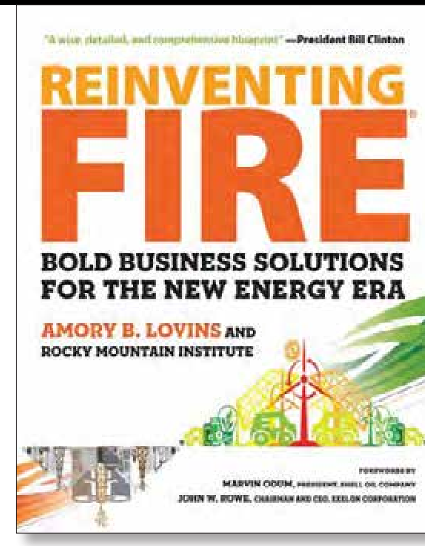
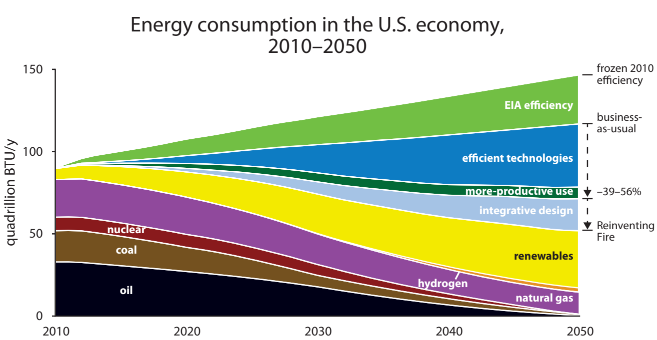
Reinventing Fire



Courtesy Chelseagreen.com (6)

Reinventing Fire: Bold Business Solutions for the New Energy Era by Amory Lovins and the Rocky Mountain Institute (2011, Chelsea Green Publishing Co.)

Many public policy books contain brilliant and insightful analyses of a problem and then totally fail by offering solutions that call upon us collectively to try merely harder, delay or forgo gratification, and/or fundamentally behave in ways contrary to human nature. But energy guru Amory Lovins of the Rocky Mountain Institute (RMI) and 12 coauthors have written a self-help book to break this country's addiction to fossil fuel. Their roadmap would end all coal, oil, and nuclear energy consumption by 2050. By that time, wind, solar, and other renewable sources would provide 43% of the country's energy with much of the rest coming from non-cropland biofuel, hydrogen, and hydro-electric. Natural gas would fill out the energy mix, but at a level of between 14% and 36% less than what was consumed in 2010.



The path charted in *Reinventing Fire* could phase out oil, coal, and nuclear energy by 2050. Natural gas use would be from 14% to 36% below the 2010 level.

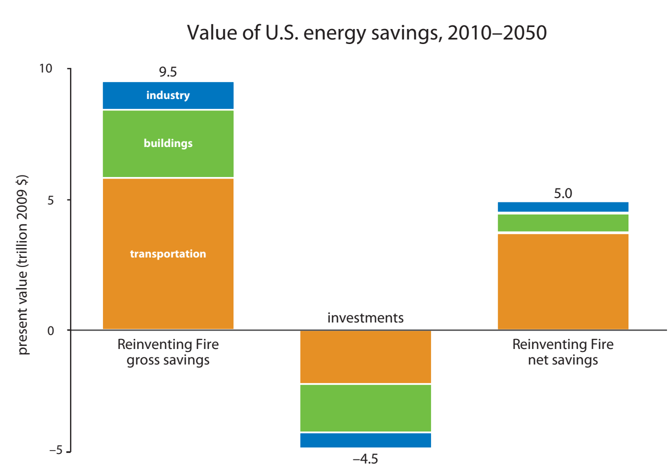
RMI doesn't appeal to our better natures as much as to our pocketbooks. The authors project that the "twin transition" to energy efficiency and renewables—a $4.5 trillion investment—would result in a $5 trillion net profit to society—if we spend the money to wisely transition from fossil fuels to energy efficiency and renewable technologies.

RMI boldly claims that society doesn't need carbon taxes; Congressional action; or any new "national" taxes, subsidies, or mandates to achieve its multifaceted energy plan. "There is obviously no silver bullet—but there is a lot of silver buckshot and birdshot," notes RMI.

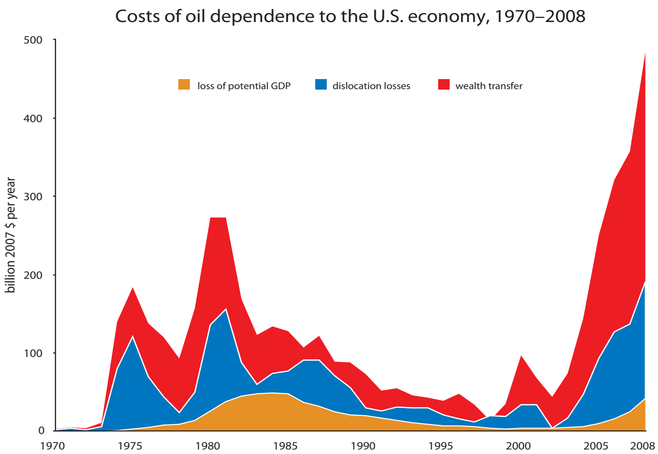
The 759 detailed endnotes and many charts, graphs, and illustrations illustrate some of that buckshot and birdshot. The book is full of examples that are enlightening and compelling:

- We could cut our gasoline use by 1% to 3% if all our vehicles' tires were properly inflated.
- The wire gauge for a lighting circuit is specified to prevent fires. If it were one gauge larger, the investment in the more expensive wire would yield a 169% savings after the tax return on the investment in saved energy.
- Compressing air to run our tools and factories uses 9% of all U.S. industrial electricity. Fixing leaking compressors can cut energy consumption in half and have a six-month payback.
- Using smaller pumps to convey materials through larger pipes with fewer and less-angled bends drastically reduces friction that must be overcome by using energy. Right-angled connections are common primarily because they are easier to draw on the plans.

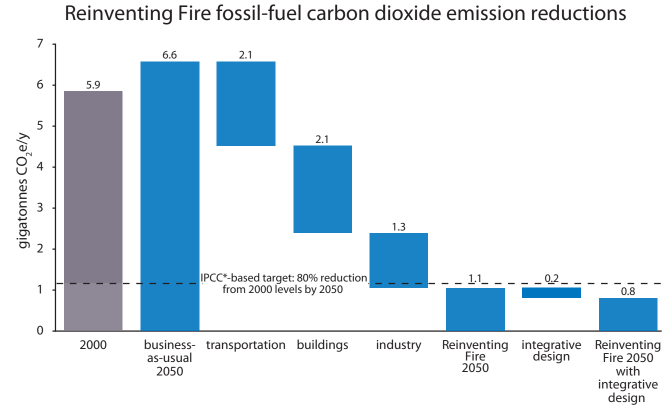
The book admits that freeing ourselves from fossil fuels won't be pain-free, but the multitude of pleasures—from healthier people to enhanced national security—are a huge net gain. Yes, we can have 125 to 140 mpg-equivalent cars, but also trucks that run on 30% less fuel (none of it diesel) and planes that use several-fold less fuel (none of it kerosene).



Discounted to 2010 present value at a 3% per year real discount rate, the *Reinventing Fire* strategy would require $4.5 trillion of cumulative extra investment (beyond business-as-usual practices) but return $9.5 trillion in fuel savings, creating $5 trillion of cumulative net wealth.



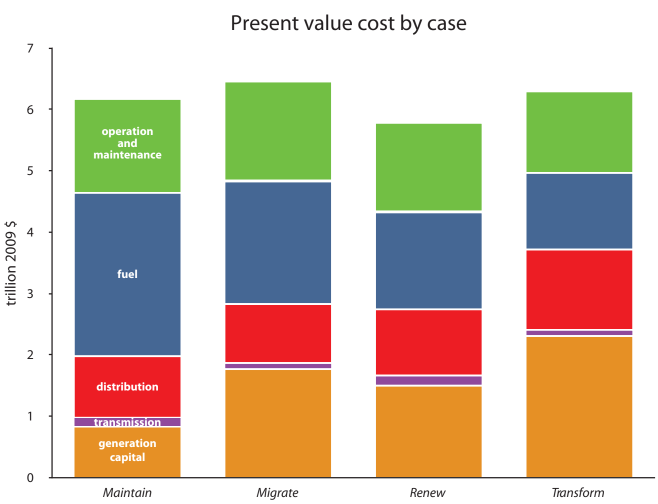
***Reinventing Fire* notes: "In total, U.S. oil dependence's economic cost just in 2008 was on the order of a trillion dollars beyond the cost of the oil itself. The only escape is to stop using oil."**



***Reinventing Fire*'s energy savings and supply shifts can reduce U.S. fossil-fuel carbon emissions by more than 80% from 2000 levels—the minimum reduction needed to hold atmospheric CO_2 below 450 ppm.**

How? RMI says that "the logical goal, therefore, is achieving vehicle 'fitness'—designing out weight, aerodynamic drag, and rolling resistance." Once autos are extremely light and efficient, then you can focus on the power train and change how autos are propelled and fueled." Of course, Detroit and Tokyo are doing the opposite.

RMI's examination of electricity considers four scenarios: We can *maintain* what we have, replacing existing generation sources as they wear out with cleaner coal and nuclear plants; we can *migrate* to low- and no-carbon fuels in a gradual transition; we can aggressively *renew* our energy away from non-renewable fuels; or we can go all-in and *transform* our electricity system by greatly increasing distributed generators such as rooftop solar, small-scale wind, combined heat and power systems, and fuel cells. After examining the costs and benefits of each, RMI finds that the present value costs of each case are very similar. With the costs being the same, they argue, why not go for the scenario that makes us the most secure, healthy, and wealthy?



The total 2010 present value of electrical system costs varies by up to 12% across cases, but all forecasts are by nature wrong, and these estimates have substantial uncertainties. *Reinventing Fire* says that "choices between such figures should rest much less on costs, which are roughly similar and all uncertain, than on risks, whose nature, gravity, and management differ profoundly." Choosing "Transform" means spending more money up front, but less on fuel in the future. It also means fewer vulnerable transmission lines and more rooftop solar-electric systems.

Lovins embraces capitalism, arguing that it can efficiently provide society with goods and services—as long as the market is sending and receiving the right signals. RMI also says that the concepts in its roadmap, "beyond opportunities for profit…include correcting structural weaknesses in our economy and threats to our health and our way of life." It claims persuasively that following its roadmap will create wealth, manage risk, increase innovation, and create jobs.

But no book is perfect, and I have nits to pick. First, the natural environment should be given more consideration. Hydropower is considered renewable energy but it does not renew salmon. While a portion of forest and agricultural residues can be sustainably converted into energy, let's remember to leave enough to replenish nature and natural processes.

Second, while natural gas (aka methane) is an inevitable bridge fuel to a fossil fuel-free future, RMI needs to come down harder on methane's disadvantages, acknowledging that fracking (injecting chemicals under high pressure to release gas in shale rock) is a big problem, as are leaking pipelines (methane has 25 times greater global warming potential than carbon dioxide). RMI's path can decrease U.S. carbon dioxide (CO_2) emissions by 80% from 2000 levels, but that's still a lot of carbon. The Intergovernmental Panel on Climate Change (IPCC) says that to stabilize at 450 parts per million (ppm) of atmospheric CO_2, an 80% to 95% reduction in CO_2 emissions from 2000 levels will be necessary. IPCC has also concluded that its earlier worst-case scenario is the actual case now. Many scientists now say that 350 ppm must be the target number (350.org). We're presently at 393.09 ppm (co2now.org) and rising.

Nitpicking aside, *Reinventing Fire* shows us that we neither need to freeze in the dark, nor go back to the Stone Age, to ensure a healthy, habitable planet for ourselves and our descendants.

—reviewed by Andy Kerr


Nature provides us with the gift of energy through the sun, but unfortunately, nature's wrath may not be all that friendly to your PV system under stressful conditions. Snow, wind, extreme heat or cold, and seismic activities can wreak havoc on underengineered, underdesigned and insufficiently tested racking structures. Only UNIRAC solar structures have been engineered and third-party tested to withstand the harshest of elements and events for a long and enduring service life. Complies with IBC, IRC, ASCE-7-05, ADM, AISI, AISC, NEC and UL. For the highest level of engineering and construction with the lowest cost of ownership in the business, Unirac is the 24/365 solution for performance in and out of the sun. Visit unirac.com for more information.
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Courtesy Stiebel Eltron

Stiebel Eltron

Accelera 300 Heat Pump Water Heater

Stiebel Eltron's (stiebel-eltron-usa.com) Accelera 300 is an air-source heat pump with an 80-gallon tank that heats and stores domestic water. It is designed to heat about 50 gallons to 140°F; a 1,700 W electric backup heating element provides supplemental heating when more hot water is needed.

Heat pump performance is evaluated by the "coefficient of performance" (COP) ratings (the higher the value, the better). A typical conventional tank-type electric water heater's efficiency may range from 0.8 to 0.95; the Accelera's COP is 2.51, which means it uses about one-third of the energy of an electric water heater. (Note that the COP is greater with higher ambient air temperatures and higher relative humidity.)

As a side benefit, in warm climates, the water heater can be placed inside the home and it will cool the air around it, reducing the air-conditioning load. In cold climates, the unit can be placed in a basement to act as a dehumidifier. The Accelera 300 carries a 10-year warranty.

—Justine Sanchez

SMA America

New Sunny Island Inverter Models

Courtesy SMA America

SMA America (sma-america.com) introduced two new models to its line of battery-based inverters for use in off-grid or grid-tied backup power systems. The 4548-US and 6048-US models join the existing 5048-US Sunny Island inverter. The 4548 model has a continuous output rating of 4,500 W, while the 6048 is rated for 5,750 W. The 4548-US and the 6048-US have CEC-rated efficiencies of 94.5% and 94%, respectively. Both models can surge to 11,000 W for three seconds and have 120 VAC output. However, they can be stacked for 120/240 split-phase and three-phase operation. Both require 48-volt battery banks, and have 85 A battery chargers. No-load draw and standby consumption is 25 W and 4 W for both models. These inverters come with a five-year standard warranty, which is extendable to 20 years.

—Justine Sanchez

Pete Fine – Owner of US Solar Works, a Massachusetts AllSun Tracker installation partner

Pete is another member of our growing team of installation partners who have discovered the AllSun Tracker complete system advantage for installations large and small.

"My solar customers are smart, high tech and savvy about their business. They prefer the clear statement trackers make," Pete says. "As an installer, I love trackers because they're rugged, well designed, easy to install and able to handle our tough Northeast weather. The extra energy produced from tracking makes the deal work."

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Computing for a Cause

By tapping into and consolidating unused computing power, the World Community Grid is helping fast-track research—including finding new PV materials.

Essentially a virtual supercomputer, the World Community Grid (WCG) pools the spare time of volunteered personal computers across more than 80 countries to provide nonprofit research projects with high-speed computing that their researchers otherwise could not afford. Its massive power can accelerate research time at a fraction of the cost.

"It's safe to say that World Community Grid would consistently place in the top 15 supercomputers if it were a traditional, physical supercomputer," says IBM spokesperson Ari Fishkind. "When a university or other institution purchases a supercomputer, it is usually shared by hundreds, if not thousands, of researchers. Rarely does one single research project have access to the equivalent of an entire supercomputer to itself, 24/7. However, this is what the researchers effectively get with World Community Grid."

WCG uses the idle time of Internet-connected computers to perform research calculations. Once downloaded by the volunteer user, WCG software works in the background, using spare system resources to process small computing assignments. When computations are completed, the software sends the results back to the server and requests another assignment. To ensure accuracy, the WCG servers send out multiple copies of each work assignment, and researchers validate the results.

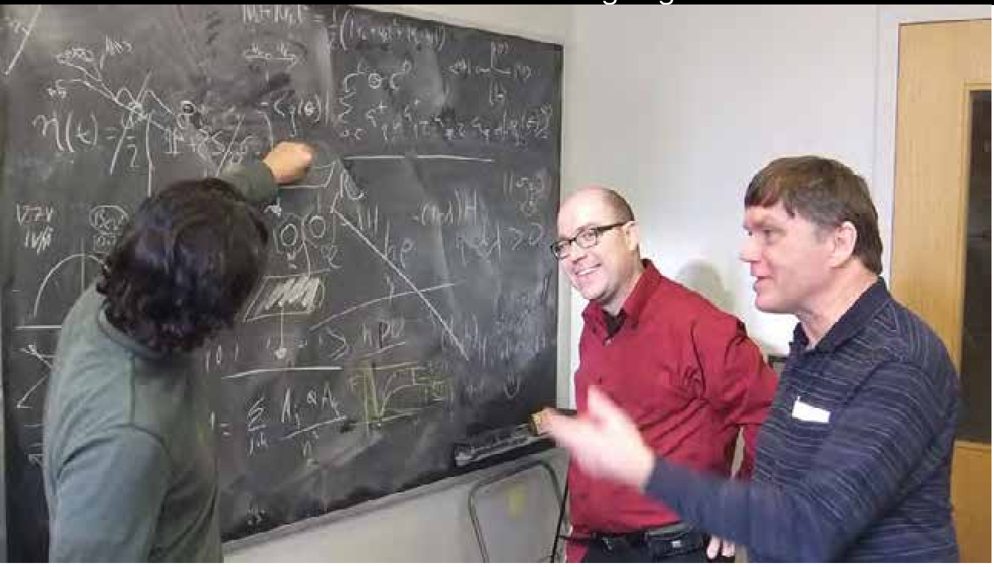
"While the central processing unit [of the user's personal computer] does consume additional power when it is processing an item on the to-do list, the rest of the machine is the major consumer of power—just by being plugged in and turned on. World Community Grid puts that otherwise wasted power to good use by computing some research that will ultimately help humanity and the world," says Viktors Berstis, the WCG's lead architect. "And, we don't ask people to keep their computers turned on more than they normally would. The system is designed to handle the pauses and resumption in calculations without any problems."

The WCG can be completely customized by users so that their PCs are always running quickly and efficiently. For instance, WCG can be the lowest-priority task for the PC so that it instantaneously relinquishes control to the user's "normal" work. The default is for WCG to use a computer's central processing unit (CPU) at levels of 60%—meaning that if the computer hits 60% for all tasks it is doing, then WCG stops using it. Users may lower the utilization even further if desired.

"Users can instruct WCG to start crunching numbers when it's clear that the machine isn't in constant use, such as if their PCs have been idle for a certain number of minutes. On the flip side, if a user has a modern, fast PC and wants to make greater contributions to WCG, then the computer can crunch numbers in the background while a user does lightweight tasks such as checking email," Berstis says.

Since WCG's launch in 2004, nearly 600,000 individuals and organizations have volunteered spare time on 2 million computers and completed 1 billion computation assignments to advance a total of 21 research initiatives. At any given time, the WCG supports a variety of projects—12 currently. Such projects include efforts to develop cancer, malaria, and AIDS drugs; identify healthier and hardier strains of rice for developing countries; and engineer better means for filtering water. Users are included in all projects by default but may opt out of projects as they choose.

The research supported by WCG has yielded some 33 peer-reviewed papers, including one from Harvard University that discusses a new organic compound that may have the potential to form a new generation of flexible and lightweight solar cells. Because physically creating material with those molecules on a trial-and-error basis is too slow, the Harvard Clean Energy Project, led by theoretical chemist Alán Aspuru-Guzik, is relying on the WCG to complete computational models that will identify molecules that may make good semiconductors. All told, the team plans to screen as many as 10 million molecules using their automated quantum chemical calculations. According to Aspuru-Guzik, the WCG allows them to characterize about 25,000 candidates



Courtesy Harvard Clean Energy Project

Theoretical chemist Alán Aspuru-Guzik and the team at the Harvard Clean Energy Project use the WCG to test hypothetical molecules' photovoltaic abilities in a fraction of the time that actual experiments would take.

More Online

Learn more about the World Community Grid (WCG) at **worldcommunitygrid.org.**

every day, compared to the few tens or hundreds that a conventional study could investigate in a month. So far, the initiative has inspected more than 3 million molecules. The team identified one new compound and shared the findings with researchers at Stanford University, who synthesized the molecule and confirmed its properties as a potential semiconductor.

"Nobody has ever computed so much quantum chemistry calculations together. This is actually terabytes and terabytes of data. The question is how to mine it, how to understand it," says Aspuru-Guzik. "This is actually what we are concentrating on right now, and the WCG allows us to do that."

—Kelly Davidson

Form & Function Pay Off

Courtesy Brian Pettepiece

At the Westport Winery on the Washington state coast, the buzz isn't only about the wine—it's about the *watts*. With award-winning wine and a replica of the Westport Lighthouse incorporated into its structure, the winery already stood out. But now it has something else to boast about: a PV installation that does double-duty. A true building-integrated solution, the entire array acts as the roof for Westport's outdoor seating area, providing guests with shelter to enjoy their wine and meals.

In a part of the state with up to 190 days of rainfall each year, the choice of modules and the array's design were important. "The double-glass construction of these Silicon Energy modules is well-suited to this type of installation. Light can pass through them, providing illumination to the seating area below," says Scott Hollis of Global Green Energy. The PV modules are offset horizontally, with each one sitting slightly underneath the one above it. The offset modules shed rain and keep the seating area dry. The design creates structural functionality from a PV installation with the modules providing the roofing material. Compared to a traditional roof-mounted system, the canopy-mounted modules also have more airflow around them, which can help keep the array cooler (and performance higher) on hot, sunny days.

"Working with a professional building engineer, we designed the headers and columns to support the load of the PV modules and the pre-engineered trusses," says Hollis.

Form and function were equally important to Blain Roberts, the winery owner: He wanted an array that would complement the architecture and also make good financial sense. "We weren't going to do this unless we could amortize the cost—we didn't want to make a bad business decision." Roberts estimates that the PV array will pay for itself in as little as four years and continue to reduce the winery's electricity bill for many years after that. "That, combined with the tax benefits, makes the numbers work," he explains.

Overview

Project name: Westport Winery

System type: Grid-tied PV

Installer: Global Green Energy

Date commissioned: June 2012

City: Aberdeen, Washington

Latitude: 46.9°N

Average daily peak sun-hours: 3.77

System capacity: 7 STC kW

Average annual production: 7,440 kWh

Average annual utility bill offset: 38%

Equipment Specifications

PV modules: 36 Silicon Energy Cascade series, 195 W STC each

Inverters: 2 Silicon Energy SiE-SIS-4.2, 4.2 kW

Array installation: Building-integrated patio awning

Array azimuth: 180°

Tilt angle: 22°

Looking up through the underside of the solar awning with sunlight breaking through the checkerboard pattern, he smiles. "It makes for a really interesting space," he says. When building functionality and aesthetics combine to create a usable structure that actually pays you back, the result is good news for any business owner—but for Roberts, it's sweeter than the wine.

—Brian Pettepiece

Kenya, Pokot Tribe of Masai People

Interrow Shading

If not spaced correctly, tilted rows of PV modules—a common layout for low-slope roofs and ground-mounted arrays—can end up with the tops of one row shading the bottom of the row behind it. In some cases, the entire production of the partially shaded rows can be curtailed.

A common approach is lay out the array to avoid interrow shading between 9 a.m. and 3 p.m. on the winter solstice—the day when the sun is at its lowest angle and has the narrowest range of azimuth angles. The shadows cast on this day are longer than on any other day of the year.

The amount of shading depends on the row spacing. The required spacing can be calculated based on the site's latitude (the higher the latitude, the longer the shadow); the row height above the ground or the roof surface (the taller the rows, the longer the shadow); and the desired solar window (more space will be required to avoid interrow shading with a wider solar window).

For this example, the PV array is assumed to be facing true south and on a flat surface. If the height (H) of the modules' top edge above the roof or ground is known, along with the sun's altitude (y) and azimuth (z) angles at the start (or end) of the desired solar window, then the required distance (D) between the back of one row and the front of the next can be calculated as:

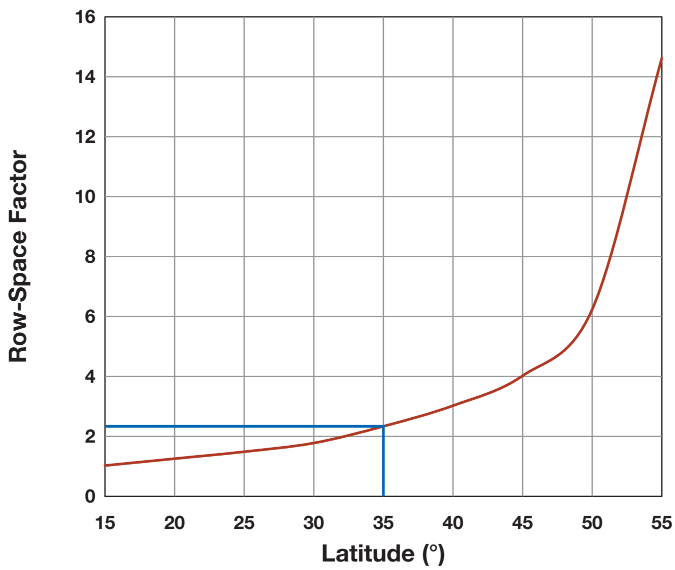
D = [H ÷ tan(y)] × cos(z)

But, let's face it: Many people prefer to avoid trigonometry, so the formula was used to draw a graph which gives the interrow spacing factor to avoid shading from 9 a.m. to 3 p.m. The graph's x-axis is the latitude of the site and the y-axis is the row-space factor. Simply multiply the factor for your latitude by the row height to calculate the space required between the back of the one row and the front of the next.

This graph works for arrays facing true south on a flat surface. If the array isn't facing true south, and/or the mount surface is pitched, then the calculations become more complicated and you'll have to brush up on your trig!

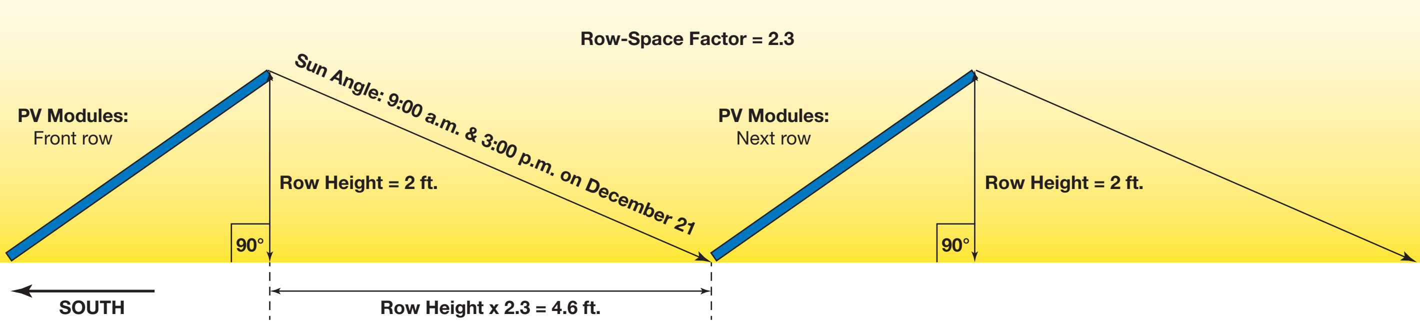
—Brian Mehalic

Row-Space Factor for 9 a.m.–3 p.m.



Multiply the row-space factor by the module height to get the necessary distance between rows of modules.

Interrow Spacing at 35°N Latitude



Homebrew Wind

I grew tired of cranking up the old gas generator each time we lost power during winter outages. I said to myself, "I want to do something different—something simple, easy to maintain, something low-cost that I can handle by myself." And now, five years into retirement, I have this 100-foot-tall monster standing in my backyard.

I started researching building a wind turbine on the Internet, and gathered as much information as I could. Two excellent resource books I recommend are *A Wind Turbine Recipe Book* by Hugh Piggott and *Homebrew Wind Power* by Dan Bartmann and Dan Fink.

Constructing the lattice tower was a time-consuming effort. I had to learn to weld and use a cutting torch. The tower is constructed from steel tubing (the top rails of chain-link fence). I located my tower carefully among the large trees in my backyard. I used the oak trees, a 6-ton pulley, and a 5/16-inch steel cable system—raising the tower using a second pulley connected at two different stress points along the tower with a 12-volt, 12,000-pound winch. An oak tree acts as a "gin pole" to raise the turbine; other trees help support the main tree (you can pull one over, trust me). I can push a button to raise and lower this homemade renewable energy system.

Anyone handy with tools and who has patience to learn can create a similar device, even if at a lesser height or capacity than this project. The turbine is just a simple homemade alternator, using a six-stud trailer-wheel hub with two bearings. With 32 rotating rare-earth magnets next to a three-phase fixed stator wound by hand with #10 copper coils, there's really not that much to it. I like to keep things simple—I went with this design because it's simple and it works. I'm always working on it, enhancing it, and making it better. I've seen it generate more than 3 kW at times. With a 1 kW solar-electric array, I've been pleased with the results—cutting about 30% off the old electric bill.

Courtesy Roger Beale

This is a 48-volt hybrid (wind/solar) off-grid system with three parallel Magnum Energy inverters that feed a separate 150 A breaker panel in our home to provide standard 120/240 VAC electricity. The hybrid system charges 16 deep-cycle golf-cart batteries, which gives us at least 24 hours of backup with no wind or sun energy input.

The solar-electric array is eight 12 V, 130 W modules, with two groups of four in series to provide a 48 V output. The other four modules are configured in the same way. Both 48 V series strings are then connected in parallel to a 60 A Morningstar controller. The array is mounted on a large frame with 12-inch casters and tie-downs, so I can easily rotate it on the deck to maintain a higher level of performance, morning to sunset.

The turbine and solar-electric modules maintain a good charge on the batteries. I use a Morningstar relay driver to monitor battery voltage and amperage, and it automatically switches if there's wind or solar energy to be had. I also have the relay driver programmed to apply a dynamic braking relay (shorting out the three-phase alternator) if turbine blade overspeeding occurs (the battery voltage suddenly rises) or if the Morningstar diversion controller or load resistor fails.

I would have paid more than $25,000 to purchase such a system commercially. My project cost was between $5,000 and $7,000, including the batteries.

Roger Beale • Evington, Virginia

Long-Lasting Gear

My Solar Electric Systems charge controller, installed in 1984, was limited on the number of modules it would handle. So when I added solar capacity in 1989, I added a Trace C30 controller to handle four more PV modules. These controllers have been in use continuously up to the present. I have never recalibrated them; I have never done anything to them. When I test the battery

voltage on a sunny day, the meter always indicates a fully charged condition. I use very little energy these days, mostly to run my 12 V submersible pump. I have no problems; I just wanted to let you know how long-lasting my solar-electric system has been.

Larry Behnke • High Springs, Florida

Rainwater

I was intrigued by the potable rainwater article in *HP149*, as I usually am by any articles from the United States on rainwater collection for drinking. Here in New Zealand, I was brought up in a rural area where our only supply of domestic water was from the rain. The main water tank was on a stand at such a height that the rainwater from the painted corrugated metal roof fed into it by gravity and the tank then gravity-fed all the household taps—bath, toilet, etc. Once this tank was full, it overflowed into a large, uncovered concrete backup tank. Occasionally, in very dry summers, we had to hand-pump water from the concrete tank into the tank on the stand.

Our seaside holiday house, along with all the others on the bay, is supplied with water piped from a stream. We have fitted a fine-mesh line filter to this supply, as without it, the filters on the dishwasher and automatic washing machine were inclined to block up with algae. It is much easier to wash out the line filter periodically than to clean the individual appliance filters.

We recently visited Tonga, where our church work-party was improving a water supply system. There, the town water supply is not working much more often than it is "on," and the most reliable water supply is from rainwater collected from corrugated metal roofs—some of them painted, though many not. Apart from the tanks generally having lids and, in Tonga, having insect screens across the openings, none of the filtering or sterilization measures in the *Home Power* article have been taken.

While I have read about first-flush diverters, I have never seen or made one. Neither have I come across anybody actually using a floating intake or ozone disinfection units on a domestic supply. I do not recall hearing of anybody suffering any sickness as a consequence of drinking from such water supplies. (There is now *Giardia* in some streams in New Zealand, and a water supply from one of those would need a filter to help prevent illness from this parasite.)

We do take some precautions that (somewhat surprisingly) the article did not mention. For instance, not all roof paint is appropriate. The label on the paint container I have says: "Safe water collection: Suitable for the collection of drinking rainwater. Important: While painting, disconnect the downpipes from your drinking water collection tank. Do not reconnect until after a significant rainfall has washed any surface surfactant off. Alternatively, thoroughly hose the roof with water before reconnecting."

Is the rainwater in rural areas of the United States really that much more polluted than it is in the South Pacific? Or is it that people there live in such an artificially sterile environment that they have not built up any immunity to anything and so need to take such precautions? Or is most of it overkill?

Lindsey Roke • Manukau, New Zealand

You pose some great questions. Let me say first that if it works, don't fix it. If the simpler system people are using in your area to collect and distribute rainwater is working fine, then by all means abide by the KISS (Keep It Super Simple) engineering truth—it'll be less expensive, with less maintenance and easier-to-find parts.

Regarding the first-flush diverter, there may be more pollutants stateside than in New Zealand. We certainly have a fair amount of tree cover in many areas, which can lead to contamination from bird and squirrel droppings that wind up on the roof, and widespread use of coal for electricity generation, which means a dusting of mercury-laden soot can build up on our roofs within hundreds of miles of the power plants. Additionally, leaves and other organic matter have the potential to act as a reservoir for unwanted microbes should some get in the cistern. So flushing this buildup, especially after a prolonged dry spell, is a great idea.

A tank just 10 or so feet above the home will provide usable water pressure, as you mention, but it will be much less pressure than what we are used to here (between 30 and 60 psi). A 40-foot (or taller) tower will provide more than 17 psi. Of course, conveying the water to this tower requires a pump, and said pump might as well be supplying your household water pressure as opposed to the additional expense (quite substantial) of a tower.

Rainwater collection in the states is a more novel endeavor than in New Zealand and Australia. As such, it may be a combination of our stomachs not being used to drinking local, unfiltered water, as well as not wanting to give rainwater collection a bad reputation by having someone get sick; that leads us to use sterilization procedures. I would certainly go to the trouble of having your tap water tested and analyzed to make sure there are no hidden troubles lurking there like heavy metals leaching from lead solder in the metal roof and gutters or a pathogen that might sicken a person with a less robust immune system than yours. The state of Victoria in Australia has a great checklist for rainwater collection (health.vic.gov.au/environment/water/tanks.htm).

Here in the United States, we are just recently rediscovering the many benefits of metal roofs. As such, many new metal roofs come with a factory finish that is safe for rainwater collection. The need to address repainting rarely occurs, at least for now.

Stephen Hren • earthonaut.net

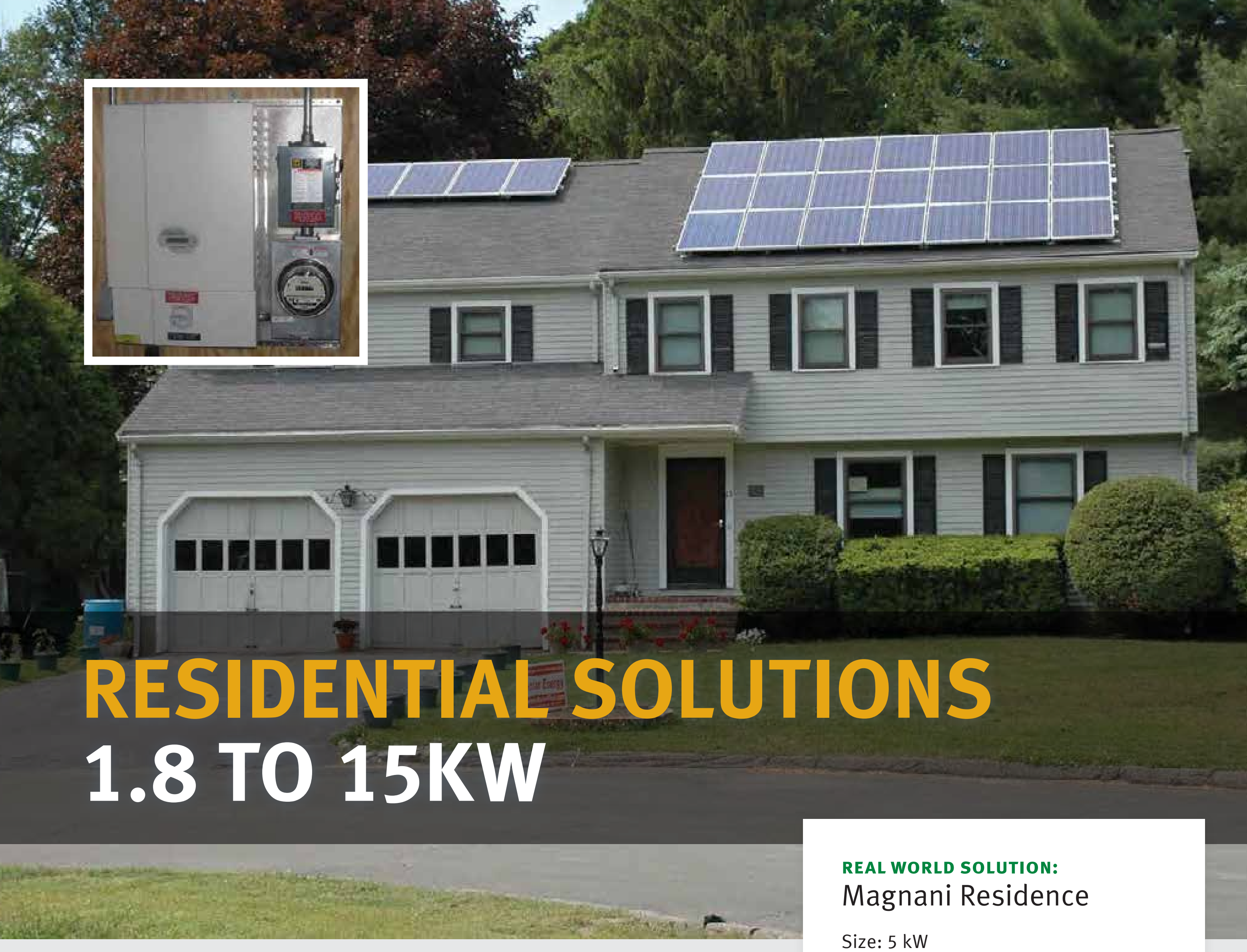
Solar Energy in Southeast Alaska

Is it for real or is it a joke? It is June 25, 2012—a dark, rainy, windy summer day in northern Southeast Alaska. It seems like the norm this year, one of the wettest and coldest on record. It is raining so hard and the cloud layer is so low I can barely make out Lincoln or Hump Islands, a scant 7½ miles from our remote cabin on Shelter Island near Juneau. I shouldn't complain too much; after all, it's by choice that I live in a rain forest.

As I look out the window, I smile. It is 11:43 in the morning and 203 W of solar electricity is being generated. Our PV system is working, generating enough energy to power three laptop computers, occasional overhead lights, and our energy-efficient dishwasher. By 5:30 p.m., it is raining harder and visibility is less than 3 miles. Lincoln and Hump Islands have disappeared into a thick gray abyss and solar output is down to 174 W, but generating more electrical energy than we are consuming. I like solar energy.

My wife Eileen, children Jayleen and Jason, dog Merlin, and I have been living in our three-bedroom, one-bath, 1,300-square-foot cabin for 10 years. We have an electric dishwasher, four laptop computers, microwave, freezer, washer, toaster, blender, hair dryer, TV, water pump, and switchable lights in all of the rooms. We also have a propane cook stove, fridge, and clothes dryer.

Living remotely and off-grid can be challenging at times, and one of our biggest challenges has been to provide electricity. Conserving and using less has always been a part of living remotely, but when the cost of gasoline hit $5 a gallon, I decided that I was really going to start using less fuel and, in my own little way, try to make the United States less dependent on oil from the Middle



RESIDENTIAL SOLUTIONS
1.8 TO 15KW

REAL WORLD SOLUTION:
Magnani Residence

Size: 5 kW

Installer: solarflair CLEAN ENERGY SOLUTIONS

Location: Framingham, MA

Products: PVI 5000

"We have partnered with and chosen Solectria Renewables' residential inverters for various installations since 2005. Their residential inverters are the most efficient and reliable in the grid-tied PV market."

– Matt Arner, President and Certified NABCEP PV Installer, SolarFlair Energy, Inc.

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Courtesy Jason Beedle

East. I started using our skiff to travel to town instead of our bigger boat; the skiff has three to four times the fuel economy. We also invested in PV and wind generation systems.

Sometime around 2006, I had a wonderful talk with a world oil quantities guy for British Petroleum. I asked him, "What can we do about the high price of gasoline?" He laughed and said, "I told my father that he should probably think about getting a more fuel-efficient car." He then continued, "I think Americans should start driving cars that get better gas mileage as well—look at all these vehicles running around getting 8 to 12 miles a gallon. They should start using less energy in their everyday lives, consume less, and the price will go down."

Many Americans believe that energy produced from solar-electric modules or solar collectors is some kind of joke. They have read or heard somewhere that solar panels are inefficient, that they only work in direct sunlight and for only a few hours a day, they cost way too much, they become worthless as they age, and there is no way to store the energy for more than a short period of time. This negativity goes on and on.

Germany (a country more known for its cloudy days than sunny days) has been planning ahead for its energy needs. Not only did Germany have the foresight to start investing in solar years ago, it also updated its electrical grid to handle electricity from renewable energy. Saudi Arabia, the world's number one exporter of oil, has just announced it plans to invest $109 billion in renewable energy by 2030. It is obvious they would rather sell oil at $80+ a barrel—to those who are stupid enough to pay that much—than to use the oil themselves. They know that someday the oil reserves will run out, but the sun will continue to shine favorably on their solar panels.

Since the middle of March this year, our household has burned less than 3 gallons of diesel fuel in our cabin generator—98% of our electrical needs have been supplied by our solar-electric system. For eight months of the year, March through October, the system saves us $150 a month in fuel costs. That is $1,200 a year—and in a rain forest.

In spite of the many articles I have read that tell us solar will never be mainstream, I continue to believe solar energy has a very bright future. The United States will probably not be the major force behind solar energy farms; it will be developing countries that are willing to put up with some of the challenges that are required to live and work with solar energy, such as consuming less of everything and planning how and when they use energy. The push will also come from developed countries that are willing and smart enough to plan for the future and invest in upgrading the hardware and software to integrate renewable energy with the grid, with the insight to understand the long-term benefits of using renewable energy and the positive effects it will have on the world's ecosystem and the people who live here.

As I listen to the rain hit our metal roof on this windy, dark, cold, rainy summer day, I smile. Solar power, even in Southeast Alaska, is real.

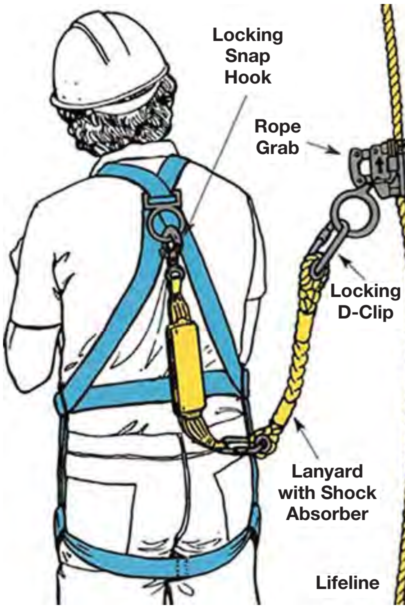
Jay Beedle • Shelter Island, Alaska

Wind Safety

As I skimmed the cover of *HP148*, I saw that a wind generator on a tall tower was in the spotlight. Being a safety fanatic, I noticed the lack of a full-body harness and what appears to be minimal fall-protection equipment. I was surprised that a rag of your status and awesome reputation would put this out there without at least an edit of these details with photo magic.

Tower climbing safety for the small wind industry is at its highest-ever public awareness, not only for the safety rule-makers, equipment suppliers, regulators, climbers, educators, and insurance providers, but also system installers and homeowners who do it themselves. A group of small-wind safety advocates (volunteers) are putting hundreds of hours into developing a small wind safety best practices document—sending it out for industry review and comment—to officially and legally define what it is we do and how we safely do it. We have worked very hard to educate, promote, and bring tower-climbing safety to the forefront of our industry to keep our windsmiths alive, safe, and in compliance. The draft *Best Practices in Small Wind: Tower Climbing Safety* document can be viewed in the "Resources" section at smallwindconference.com.

Please help us to continue moving safety forward by showing climbers who are practicing and promoting tower-climbing safety. Tower safety is not just about regulations or best practices, but also about going home that night to those who love you. "We obey the law to stay in business; we obey the laws of physics to stay alive." —Anonymous windsmith



Courtesy elcosh.org

Tammy Stoner • Le Roy, Michigan

Thanks for your letter, Tammy. The lack of OSHA-compliant fall protection in our April/May 2012 cover photo was a serious oversight on our part. Without exception, installers should utilize compliant safety equipment and be properly trained in its use. Additionally, OSHA equipment handling, storage, inspection, and documentation procedures should be followed. Home Power*'s goal is to promote best practices related to the design and installation of renewable energy systems. We fell short in this instance, and will strive to show only compliant fall protection equipment and systems in future publications.*

—Joe Schwartz,
Home Power *executive editor & CEO*

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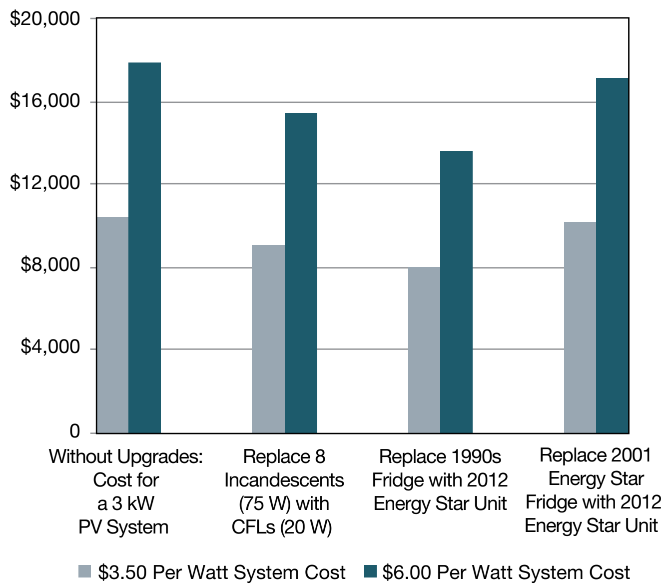
The Value of Efficiency

I've been searching your back issues for a particular article that talked about how for every $1 spent on energy efficiency, you would save "X" dollars on renewable generating capacity. Can you help me find it? I'm chairman of my town's green committee and currently serving as the "solar coach" for a program run by the Massachusetts Clean Energy Center. It's a group-purchasing plan for residents to buy PV systems at a discount. I'd like to be able to quote the article to the people on my sign-up list (currently more than 180 residents, nonprofits, and businesses). We've been quoted about $3.50 per rated watt for batteryless grid-tied PV systems (including our bulk-buy discount, but before incentives), so I suspect the ratio of savings has come down quite a bit, but is still significant.

Andy Boyce • Hopkinton, Massachusetts

PV System Costs & Efficiency Upgrades



The general estimate that *Home Power* had been using for many years is that for every $1 you spend on efficiency and conservation measures, you save $3 to $5 on a *battery-based off-grid* PV system. As you point out, this ratio may have decreased, because the cost of PV systems has gone down significantly since the earliest days of the magazine when an off-grid PV system may have cost $15 per installed watt.

Since then, PV system costs have decreased significantly, while appliance efficiency has increased. That means homes are generally more efficient before their owners even start to consider how best to spend their energy dollars. That also means that some of the low-hanging fruit of energy efficiency has already been picked, and further gains from efficiency investments are likely to cost more per the same amount of energy saved.

It would be great if we had a way of more accurately quantifying this estimate on a whole-house basis—that exercise could become somebody's master's thesis. However, it is much easier to do this for a particular location on a load-by-load basis.

Let's look at an example of changing incandescent lightbulbs to compact fluorescent bulbs. While this may be the most likely of previously picked low-hanging fruit, it demonstrates one small but important aspect of the efficiency gains that can save us money on our PV systems. Personally, I live in a small off-grid home and rarely have more than two lights on at a time. But I can imagine tens of thousands of inefficient homes that might average eight or so lights on for three to four hours a day.

Incandescent:
8 bulbs × 75 W × 3 hrs./day ÷ 1,000 W/kW = 1.8 kWh/day

CFL:
8 bulbs × 20 W × 3 hrs./day ÷ 1,000 W/kW = 0.5 kWh/day

That is an energy savings of 1.3 kWh each day, for an initial investment of about $36 for quality CFL lights. Just this one simple efficiency investment translates into a 0.4 kW reduction in a batteryless grid-tied PV system's size.

At your mentioned installed cost of $3.50 per W (a very good deal), that turns into a total system cost savings of $1,400 (0.4 kW × $3,500/kW). In this case, for every dollar you spend on compact fluorescent lightbulbs, you will save $38.89 ($1,400 ÷ $36) on the cost of your solar-electric system. Wow, that's *huge*.

Of course, as you get into more expensive items like clothes washers, refrigerators, etc., the energy savings will be lower, while the upgrade cost is higher. Upgrading from a 1990s model refrigerator to a 2012 Energy Star unit can save about 2.4 kWh per day, which translates into a $2,490 system savings at $3.50 per installed watt. With an $800 fridge, the ratio is about $3.11 saved for every dollar spent.

Upgrading from a 2001 Energy Star fridge to a 2012 unit saves about 0.35 kWh per day, resulting in a PV system cost savings of only $364—significantly less than the upfront investment of buying the new $800 fridge.

As you can see, it is all about first picking the low-hanging fruit with your energy-savings investment, then moving on to less cost-effective items. But even a small savings ratio is worthwhile. This discussion of efficiency investments is only relative to the initial cost of the PV system. But there are other reasons and factors—such as decreasing the amount of climate-influencing pollutants and keeping ahead of the ever-increasing costs of utility-made electricity—that make investing in superefficient appliances a smart choice.

Michael Welch • *Home Power* senior editor

Careers in Solar Energy

I just read Allan Sindelar's article, "Engine Generator Basics" in *HP131*, as a part of an online PV course. According to his bio at the end of the article, Allan has been installing solar-electric systems since 1988. That's an amazing amount of experience!

Would you mind giving me some advice about becoming a solar electrician? It represents a huge investment in time and money to go through the training and apprenticeship. Would it be worthwhile to invest in becoming a licensed electrician myself, or would you recommend teaming up with someone who is already qualified?

Zach Arnt • via e-mail

I came into the field as a carpenter, not an electrician, and learned on the job, mostly by hiring employees who were electricians. This was in the early days when most solar installation companies were tiny—

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with four to five employees at most—and we did everything, including sales, design, installation, and service. It's totally different now. PV has become a commodity, and most companies are structured more like mainstream businesses.

You write that you want to help folks make renewable energy systems a reality in their lives on the residential and small commercial scale, which is a pretty general statement. If your way of accomplishing this is to become an installer, then yes, pursue an electrician's license if you want a career with a chance for advancement. But there are plenty of ways to accomplish your goal. You could specialize in sales or financing with a focus on PV systems—these don't require you to be an electrician. A system designer with CAD skills doesn't need to be an electrician, although installation experience will help tremendously. You could accomplish your goal in many different ways—as a community activist, a journalist, a graphic designer, or with a degree in business management.

Allan Sindelar, Positive Energy • Santa Fe, New Mexico

Over the years, *Home Power* has published several articles on getting into the solar industry. One favorite is "Charting Your Solar Course" (*HP136*), which outlines many ways you can get on the solar career path, and includes a comprehensive list of education programs that aim to get you started.

Michael Welch • *Home Power* senior editor

I knew when I first started to pursue a career in renewable energy that the job I wanted to do was hands-on, as a systems installer. So I took classes part-time at my local community college in electrical technology, followed by solar-specific training courses at Solar Energy International. With this initial training, I got a job with a skilled electrician who owned a solar installation company. What I gained from that job was years of real-world training, technical skills, confidence in my ability to install and design high-quality, code-compliant systems and, last but not least, the hours and knowledge necessary to get my electrical license. You mention that it takes an investment of time and money, but don't forget that apprentices get paid to work.

It has been more than four years since I got my electrical contracting license in North Carolina, and it was definitely the right path for me. While I now do more training and consulting than installing, it is reassuring to know that I will always have an electrical license to fall back on. Even if you aren't interested in a hands-on career, I still believe that training and systems installation experience benefit anyone entering the solar industry. I frequently tell students that if they get a job as an installer, even for a short time, they gain a great understanding of the industry.

Rebekah Hren • Solar Energy International

Battery Queries

The charge controller for my off-grid system is a pulse-width-modulated (PWM) taper-charge CC120E from Heliotrope General. When I open the cover, I find a DIP switch for changing the output voltage, which I assume is the absorption charge. There is no mention of the float-charge setting.

Trojan's data sheet for the 24-AGM battery recommends an absorption charge between 14.1 and 14.7 V. I can make this change with the DIP switch. However, the original setting is 14.3 V, well within the recommended range for the AGMs.

The data sheet also recommends the float charge at 13.5 V. I am not sure how to change the float setting, or if it even is necessary. Also, Trojan recommends

limiting the maximum charging rate to 15 A. My PV system will provide as much as 80 A. How do I control this?

I had planned to start with a single AGM battery and if it went well, add additional ones in parallel later. I've heard that it's a bad idea to do this, and I understand the reasoning. But what do I do if one of the original batteries goes bad? Do I then replace all of them? This could be very expensive.

Charlie White • via e-mail

The manufacturer of your specific controller closed its doors almost 12 years ago, so I would strongly recommend buying a modern PWM solar charge controller. They are not that expensive and feature a lot of bells and whistles that would greatly help maintain your battery bank properly. To answer your points:

- The "absorption" voltage setting of Trojan deep-cycle lead-acid batteries is given as a range because there are various renewable energy (RE) applications they can be used for. Typically, the higher value is used for an adequately sized stand-alone PV-only system, since there is a limited time of solar energy availability.

An "absorption" voltage setting for the VRLA AGM cannot be lower than 14.1 V for a 12 V battery bank configuration, otherwise it would not charge the battery properly. This value should be temperature-compensated to account for the battery bank's temperature, which requires a temperature probe within the battery bank, and connected to the controller.

- The float-charge is key to the battery's health, helping to finish the charging. Without it, the battery will eventually face sulfation. Please check the charge controller's manual to find out if there is an additional DIP switch related to the "float" charge phase. If there is no other DIP switch, perhaps the float-charge default set point is meant to be the same as that of the flooded lead-acid (FLA) batteries.

The FLA voltage setting for "float" is 2.20 volts per cell (13.2 V for a 12 V nominal battery bank). For AGM batteries, it is 2.25 VPC (13.5 V). The lower 13.2 V setting is OK for AGM batteries, provided that the system regularly gets to float voltage for a few hours each day. Buying a modern PWM controller will put this concern to rest, since the AGM's set point will address both the "absorption-regulation" and the "float" voltage settings at once.

- During "bulk" charge, the battery will accept any amount of current from the PV array until reaching the "absorption-regulation" voltage set point. After that, the controller regulates the charging amperage to maintain that voltage.

- Starting with a single AGM battery and adding additional ones in parallel later is a very bad idea, and will result in damaged batteries. It is best is to size the initial battery bank and PV array adequately, to use a modern PV controller, and then to commission the system with appropriate voltage settings.

John F. DeBoever • Trojan Battery Company

write to:

asktheexperts@homepower.com

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

PV Rack Innovations

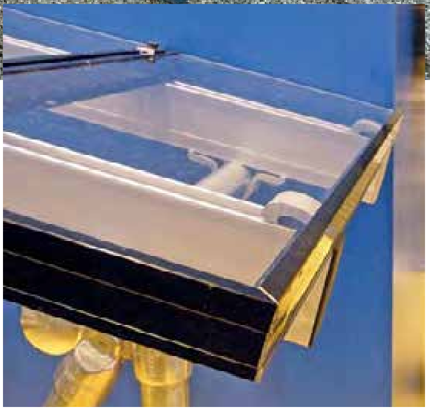
by Rebekah Hren

Shawn Schreiner

Whether roof-, ground-, or pole-mounted, PV rack and its associated parts, such as structural attachments, grounding, and wire management systems, are available in hundreds of styles and varieties. There has been a recent explosion of companies that offer PV racks.

Just as when you're selecting PV modules or inverters, cost shouldn't be the primary factor in choosing PV racks. Company sustainability and longevity, product warranties, aesthetics, the level of customer and engineering support, and *Code*-compliance—all of these factors should play a role in deciding what rack system to rely on.

No two solar sites are precisely alike; both the built and natural environments affect an installation's specifics. A thorough site survey quantifies these factors, and a quality system requires tailoring the design to the site specifics (see "Solar Survey" and "Optimal PV" in *HP130*). Working with PV rack companies can take much of the guesswork out of the process, as they will provide engineered designs to meet wind uplift forces, snow load, and soil or roofing material types.



SnapNrack pitched-roof mounting systems have integrated wire management channels and flashing-integrated roof mounts. End clips fit under the module, so rails can be flush with the end of the module.

Courtesy SnapNrack (2)

Roof-Mounted PV Arrays

Because of space limitations, ground-level shading, and the excavating and trenching required for pole and ground mounts, the least expensive and most frequent location for PV arrays is on a roof. (For a general survey of rack types, see "Rack and Stack" in *HP124*).

Roofs can be classified as either low- or steep-sloped—low slope generally means a roof with a pitch of less than 3:12 (less than 14°). Low-sloped roofs are often mistakenly referred to as flat roofs, but no roof is ever really flat, as a pitch is needed for shedding water. Even a roof that appears flat will have a pitch of at least 0.5:12.

Unirac's new (E)volution rack, with I-beam rail and bonding-integrated mounting hardware, was designed to increase installation speed.

Courtesy Unirac

Top-Down Innovations

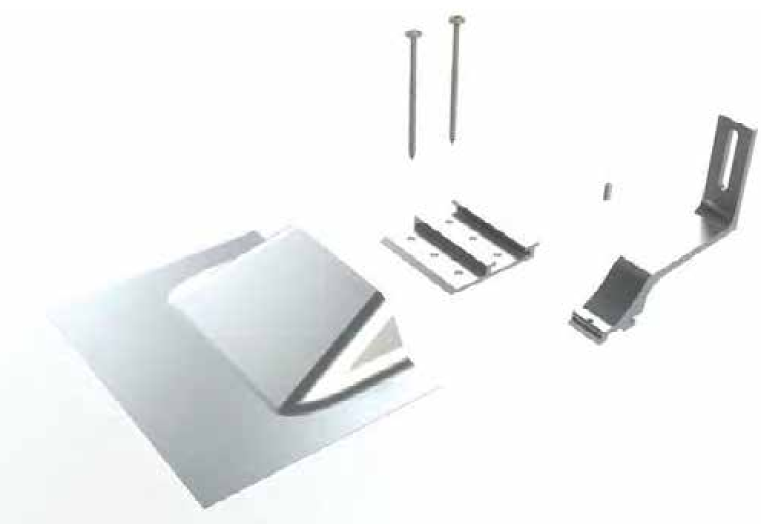
On steep-sloped roofs, modules are almost always flush-mounted—mounted parallel to the roof plane. The most common technique for flush-mounting steep roof arrays is "top-down mounting." Anodized aluminum rails are used to support modules, and stainless steel or aluminum compression clips hold the modules onto the rails, usually with a bolt and nut captured by slots in the rails. This speeds up installation, eliminating bolting through the mounting holes on the back of module frames as was once common. Now, installation is easily accomplished with the modules in position on the rails from above—thus, the description "top-down" (see "Modern PV Roof Mounting" in *HP137*).

Recent design improvements in top-down mounting decrease materials and reduce labor. They include automatic grounding (module bonding via the mounting clips—see the "New Criteria, Listings & Techniques" sidebar) and one-tool installation (all of the bolts have the same size head).

SnapNrack, a pitched-roof mounting system developed by solar installers, was designed so one wrench fits all bolts. Snap-in nuts attach standoffs and top-down clips, the rails are height-adjustable, and there's a built-in channel for wire management. In addition, both the mid- and end-clips have a universal design, meaning that regardless of module-frame dimensions, a single clip works with any module and the clips don't have to be specified in advance.

Courtesy Quick Mount PV (2)

Schletter's Gator mount for composition roofs uses a flashing-integrated mounting block, which attaches via a single hanger bolt to the roof structure and the Gator Clamp solar rail attachment.



Quick Mount PV's new Quick Hook tile mount is the first commercially available flashed tile hook mount.

Structural Attachments

Structural attachments from the array to the roof are a critical part of the installation. The attachment type and method will vary based on the roofing type (shingle, metal, tile, etc.) and with the roof's structural design (wood trusses, structural insulated panels, metal purlins, etc.).

Preventing roof leaks and meeting building codes for live and dead loads (including wind uplift, rack and array weight, and snow loads) are primary concerns. A properly installed array will meet these concerns and maintain the roof warranty. In nearly all installations, every roof penetration needs to be flashed for waterproofing. On a composition (asphalt) shingle roof, the metal flashing fits underneath higher rows of shingles, so water runs over the top of the flashing and around the roof penetration. For years, many installers relied solely on sealant for penetrations, but new structural attachments make installing flashed penetrations simple and quick.

Quick Mount PV manufactures flashing-integrated brackets for a wide range of racks and roofing materials. Their newest products, the Quick Hook curved and flat tile mounts, are the first flashed tile hooks available. Quick Mount PV has also partnered with Schletter to create the Gator Mount—an aluminum-flashed mounting block that attaches to a composition roof and to the Schletter Gator Clamp via a single hanger bolt. Other companies offering flashing-integrated mounts include EcoFasten, SnapNrack, ThomsonTech, Unirac, and Zep Solar.

Standing-Seam & Corrugated Metal Roofs

Standing-seam metal roofs present their own challenges for installing PV arrays, as it isn't possible to flash penetrations on existing metal roofs without replacing large sections of roofing material. S-5!'s PV Kit offers nonpenetrating clamps attached with set-screws, along with PV mounting clips, for dozens of standing-seam profiles. Regardless of the array attachment, the metal roof itself must be sufficiently fastened to the structure, as the PV array adds more uplift force and weight.

An option for standing-seam roofs is the ACECLAMP JR, which, instead of using set screws to attach to the metal seams, uses a 1-inch clamp bar, which is set from the clamp's top, rather than its side.

Exposed fastener (face-fastened) metal pan, also called corrugated metal, barn tin, or 5-V tin, is another common roofing material that poses challenges for PV arrays. Flashed brackets aren't available for this roofing material. However, because the hundreds of fasteners used to attach the roofing material to the

S-5! CorruBracket (above) and VarioBracket (left) are attachment points made specifically for metal roofs with exposed fasteners.

Courtesy S-5!

Beyond Rails

The mounting rails add cost in raw materials, shipping, embodied energy, and installation labor. Zep Solar, Westinghouse Solar, and Silicon Energy offer rack systems without aluminum rails. Instead, these use PV modules with special frames that connect directly to structural attachment points. Zep Solar and Westinghouse Solar have partnered with module manufacturers to add proprietary grooved frames—providing connection points that lock onto mounting attachments. Zep systems are designed so that microinverters or DC converters can be included. Westinghouse provides an AC module option. Silicon Energy's Cascade modules are also designed to bolt directly to mounting feet and adjacent modules. They are framed only on the two long edges. Since there isn't a frame and lip on the modules' lower edges, water and dirt are more easily shed.

Courtesy Zep Solar

Above: Zep Solar's railless mounting system uses grooved modules and proprietary attachments.

Silicon Energy's Cascade modules are framed only along the long edges and attach directly to mounting feet rather than rails.

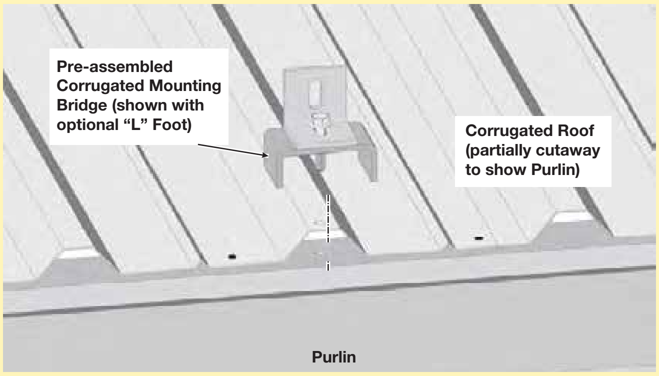
Courtesy Silicon Energy

Courtesy Lumos

Right: Frameless Lumos Solar modules are mounted on rails via hardware attached directly through the module, rather than to a metal module frame.

structure also are not flashed, it is generally accepted that PV attachment points can be unflashed as well. Second, exposed-fastener metal roofs come in a wide variety of profiles. Mounting systems for face-fastened metal roofing include DPW Solar's corrugated mounting bridge, which comes with pre-applied butyl mastic sealant and is available in different profiles to match the roof profile. S-5!'s VarioBracket is a mounting bracket designed to adjust to any profile with a trapezoidal shape. Ejot, Schletter, and SnapNrack also provide special corrugated roof saddle-mount attachments.

DPW's Corrugated Mounting Bridges are customized to fit the roofing material's specific profile.



Courtesy DPW

Schletter's corrugated roofing solution—the FixE Eternit.

Courtesy Schletter

Ballasted Systems for Low-Slope Roofs

Low-slope roofs are often associated with large commercial buildings, but in many parts of the country, particularly the Southwest, they are common on residences. Because of the rapid growth in commercial installations over the past few years, the choices for low-slope rack systems have expanded dramatically and can be either ballasted or mechanically attached to the roof.

Ballasted systems use rack and module weight, with additional mass like concrete blocks, to hold down the array and withstand wind uplift. Ballasted arrays frequently have no mechanical attachment to, and thus no penetration through, the roof. The building structure and roofing must be able to handle the additional weight, and the roofing installer and manufacturer should be consulted to ensure that a ballasted system won't void the roof warranty.

Some new ballasted systems are transitioning from the standard aluminum and steel ballast tray components to heavy-duty plastic, which is nonconductive and doesn't need to be grounded. Renusol's CS60 is made from 100% recycled polyethylene. Each PV module is mounted directly on a Renusol base, at a set 10º or 15º tilt. Sollega's InstaRack is also made from partially recycled polyethylene, and Ecolibrium Solar's Ecofoot offers another ballasted mounting solution made of a 100% recycled content polymer plastic.

Mechanically attached low-slope roof racks have several roof-penetrating structural attachment points. This, in combination with the rack's weight and design, ensures the modules can resist uplift forces. PV systems on low-slope roofs in seismically active areas usually require mechanically attached racks. Arrays with steeper tilts experience higher wind loading and may require more ballast. Less ballast may be needed if a combination of mechanical attachments and ballast is used. Nearly every major rack manufacturer has a solution for low-slope roofs, but a few, like PanelClaw's Polar Bear and SunLink's RMS, have focused very specifically on this application.

Courtesy Ecolibrium

Ecolibrium Solar's Ecofoot2 is a ballasted system made of recycled plastic.

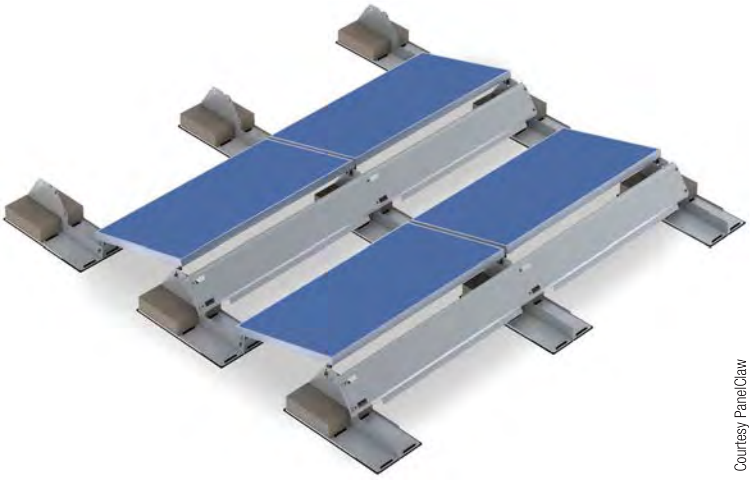
Courtesy Renusol

Renusol's CS60 heavy-duty plastic ballast trays don't need equipment grounding.

SunLink Core RMS is a low-slope roof rack solution that can combine mechanical attachment points with ballast weight.

Courtesy SunLink

PanelClaw's Polar Bear is a ballasted low-slope roof solution that incorporates recycled rubber pads under the ballast trays.



Courtesy PanelClaw

Wire Management Options

Better array wire management is also a recent focus of the rack industry. Manufacturers such as Schletter, SnapNrack, and Legrand are integrating trays or channels into rack systems to hold PV conductors. Cablofil and Snake Tray make wire management solutions that can be mounted on the back of racks. New products like the Heyco SunBundler ties, which have a UV-resistant plastic coating over stainless steel and crimp connections, offer an easy-to-install, long-lasting wire management solution compared to plastic cable ties.

Pole-Mounts, Carports & Awnings

Ground- and pole-mounted PV racks commonly rely on a combination of steel and aluminum support structures—most often using steel poles supporting aluminum rails, although all-steel galvanized racks are becoming common (see "Ground Mounts for PV Arrays" in *HP139*).

Pole-Mount Racks

The most common top-of-pole mount uses 4- to 8-inch steel poles embedded in a poured concrete foundation to support standard racks and rails. While pole mounts keep modules cooler, providing plenty of airflow around the array, there is a lot of excavation and concrete work needed to provide wind-loading support. The higher the array is mounted, the longer the buried pole needs to be.

Brian Mehalic

DPW Solar's top-of-pole mounts, set at a low tilt for high summer production.

DPW Solar's Multi-Pole mount uses 3-inch-diameter (or larger) steel poles to support a column of up to four modules in landscape orientation. 4- by 4-inch (or 5- by 4-inch) steel box tube, set horizontally, supports the module rails. The Multi-Pole mount can be adjusted from horizontal to 55º, making it a flexible solution that can be adapted to various array sizes.

DPW Solar's Multi-Pole mount can be installed at tilts up to 55° and heights up to 14 feet above the ground.

Courtesy DPW

Trackers

Trackers can also be incorporated with pole-mounted systems to increase energy production in areas with wide-open solar windows. AllEarth Renewables offers its AllSun Tracker, a pole-mounted, dual-axis active tracker for 20- or 24-module systems. Dual-axis trackers follow the sun's azimuth and altitude angle. AllSun Trackers include a string inverter mounted on the pole, and a GPS-enabled sun-tracking mechanism that replaces irradiance sensors common on residential trackers. Array Technologies manufactures dual-axis trackers, as well as residential-scale, single-axis tilt and roll trackers—also known as horizontal linear-axis trackers.

Courtesy AllEarth Renewables

AllEarth Renewables AllSun Tracker is a dual-axis tracker with pole-mounted string inverter.

Zomeworks is a long-time manufacturer of reliable, single-axis passive trackers. These passive trackers use the sun's heat and the weight of a phase-changing gas that flows through tubes to keep the rack following the sun's azimuth (east-to-west path). Zomeworks focuses on small trackers, made for residential or remote ranch applications.

Four Zomeworks passive trackers, aligned from north to south to avoid potential shading from the long shadows each casts in the morning and afternoon.

Courtesy Zomeworks

Carports & Awnings

With electric cars entering the mainstream market, more systems are being installed on carports. Lumos Solar's LSX freestanding two-car canopy comes in a 5,760 W engineered package, featuring frameless glass-on-glass modules that allow some light through the array. Silicon Energy's Cascade Series module is another double-glass, transparent module that can be installed in carport and awning structures for dappled sunlight.

General Motors, maker of the Chevy Volt electric vehicle (EV), has partnered with Sunlogics to make the Green Zone, a four- or eight-stall solar parking canopy and EV-charging station. SunPartner is another manufacturer of solar carports, offering a steel-supported 2,300 W single-stall model and a two-car, 4,600 W model, with array tilts from horizontal to 15°. Schletter makes custom carports, and their structures have even been used for solar-double cropping—for farms growing crops under and between rows of PV cover (see "Solar Double-Cropping" in *HP147*). DPW Solar's Multi-Pole mount has been installed with the bottom module edge as high as 14 feet above the ground, making it another option for a solar carport or patio cover, and DPW offers custom-designed awning mounts as well.

Courtesy Powerfully Green

Above: Silicon Energy Cascade modules incorporated in an awning structure.

Courtesy Lumos

Left: Lumos Solar's LSX engineered carport canopy.

New Criteria, Listings & Rack Techniques

The *National Electrical Code* (*NEC*) requires grounding—bonding to an earth ground through a continuous electrical path—for any piece of exposed metal that could become energized from an electrical fault. PV array racks can include many metal parts, ranging from module frames and rails to conduit, that need to be bonded. (The terms bonding and grounding are used interchangeably to mean joining metal parts to form an electrically conductive path.)

Traditionally, modules and racks have been grounded with lugs, screws, bolts, or clips attached to every module frame and to each piece of rack that might come into contact with an energized conductor—which are then connected to ground via a copper conductor. Dissimilar metals in contact with each other, such as copper conductors and aluminum module frames, will result in galvanic corrosion, reducing the effective path to ground—so stainless steel and tinned copper hardware are used for grounding. Copper conductors are costly, as is grounding hardware, and together they are time-consuming to install properly. PV system equipment grounding has been a source of much frustration, sometimes resulting in improper installation and ineffective grounding.

A new standard, Underwriters Laboratories UL2703, is sweeping through the rack industry. *NEC* 690.43(E) states that PV mounting systems used to ground modules must be identified for that purpose. A rack listed to UL2703 standards could meet this *Code* requirement. UL2703-listed racks either use piercing teeth embedded in the module clips or other module mounting hardware (like serrated nuts) to cut through the module frame's anodized coating, bonding the modules to the rack. The rack itself is electrically bonded through the hardware used to connect the individual rack pieces, so no extra grounding hardware is required. However, if a specific module hasn't been identified and listed for bonding with a specific rack, then additional module bonding may be required.

PanelClaw, S-5!'s PV Kit, Schletter, SunLink, Unirac, and Zep Solar (along with others) have mounting systems that carry the UL2703 listing. To determine if a rack is listed to UL2703, and if that listing covers a specific module's bonding, contact the rack manufacturer and the listing agency, and consult with the local authority having jurisdiction. If both modules and rack are listed, the installer needs to attach only one equipment grounding conductor to one point on each set of racks to provide a path to ground, and can forego other grounding hardware. Modules without metal frames do not need to be grounded, and neither do nonmetallic rack components such as plastic ballast trays.

The International Code Council (ICC)'s Acceptance Criteria 428 standard for PV systems provides an alternative to stamped engineered diagrams that jurisdictions can use to verify that a particular rack meets structural design requirements. ICC certification can help accelerate and lower the cost of the permitting process, as well as provide installers with a third–party verification that the rack is engineered to the standard. Unirac's SolarMount (E)volution is the first ICC-certified PV rack on the market.

Ground-Mounted Racks

One of the major differences between ground-mounted rack designs is the attachment to the ground. Many residential ground mounts use concrete piers as the structural support because they are easy to install on a small scale. Driven metal piles and anchor (earth) screws that require heavier equipment like pile drivers and use no concrete are more common on larger ground-mounted arrays. Daetwyler Clean Energy's Modu-Rack uses a single-point soil anchor, much like a giant toggle bolt, that opens to resist uplift pressure on the attached rod.

Courtesy Terrafix

The Terrafix Solarpark earth screw is a fast foundation solution for large ground-mounted arrays. Using no concrete, they are easy to both install and remove.

Ballasted racks are starting to show up more frequently on the ground as well as on flat roofs, since they can be an economical solution for paved areas and brownfields—and even for a homeowner who wants to limit ground disturbance and have an array that could be moved more easily in the future without leaving concrete piers behind. PanelClaw, SunLink, and Schletter make pre-engineered ballasted solutions intended for ground-mounted applications but nearly any ballasted rack can be used on nonsloping ground (less than 5º). Renusol's polyethylene module bases can be used on the ground as well.

Because it requires no ground penetration, SunLink's ballasted ground-mounted rack is ideal for use where soil cannot be disturbed, such as at brownfield or landfill sites.

Courtesy Renusol

Access

Rebekah Hren (rebekah.hren@gmail.com) is a licensed electrical contractor, NABCEP-certified PV installer, and ISPQ-certified PV instructor for Solar Energy International. She has experience installing and designing PV systems ranging from 10 watts to 4 megawatts. Rebekah works for North Carolina solar project developer O2 Energies.

Rack & Rack Component Manufacturers:

All Earth Renewables • allearthrenewables.com

Applied Energy Technologies • aetenergy.com

Array Technologies • wattsun.com

Cablofil • cablofil.com

Cantsink • cantsink.com

Creotecc • creotecc.us

EcoFasten Solar • ecofastensolar.com

Ecolibrium Solar • ecolibriumsolar.com

Ejot • ejot.com

Daetwyler Clean Energy • daetwylerce.com

DH Solar • dhsolar.net

DPW Solar • directpower.com

Graybar/Legrand • graybar.com

Haticon Solar • haticonsolar.com

Heyco • heyco.com

LevelOne • levelonesolar.com

Lumos • lumossolar.com

MECASOLAR • mecasolar.com

Mounting Systems Inc. • mounting-systems.us

PanelClaw • panelclaw.com

PVRacking • pvracking.net

Quick Mount PV • quickmountpv.com

Renusol • renusolamerica.com

S-5! • s-5.com

Schletter • schletter.us

S:Flex • sflex.com

Silicon Energy • silicon-energy.com

Snake Tray • snaketray.com

SnapNrack • snapnrack.com

SolarNovar • solarnovar.com

Sollega • sollega.com

SunLink • sunlink.com

Sunlogics • sunlogics.com

Sunmodo • sunmodo.com

SunPartner • sunpartner.com

Terrafix-Solarpark • terrafixsolarpark.com

TerraSmart • terrasmart.com

Thompson Technology Industries • ttisolar.net

Unirac • unirac.com

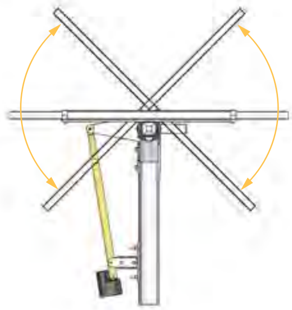
US Solar Mounts • ussolarmounts.us

Westinghouse • westinghousesolar.com

Zep Solar • zepsolar.com

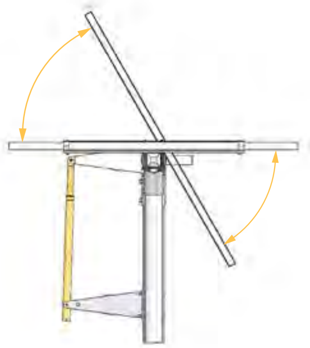
Zilla Corp. • zillarac.com

Zomeworks • zomeworks.com



DURATRACK™ LA

Get 25% more power from your system with this extremely durable, low-profile horizontal tracker that rotates from 45° east to 45° west to follow the sun. Not only can it blend into the environment, but it's also easy to assemble and can hold up to 4 kW of modules.



DURARACK™ SEASONAL

This low-cost alternative to a tracker or fixed ground mount system gives you the ability to quickly and easily optimize your array's tilt to follow the sun's seasonal changes. Adjustable from flat to 60°, this rack has a capacity of up to 4 kW DC.

More choices. Higher production. Easy installation.

Solar trackers are never a "one-design-fits-all" solution. For more than 20 years, Array Technologies has been designing high quality, low maintenance tracking and racking systems for residential, commercial and utility-scale projects. From our popular Wattsun azimuth trackers to our innovative, low-cost single-axis horizontal tracker and adjustable racks, we have the perfect solution for your project.

wattsun
SOLAR TRACKERS

A DIVISION OF ARRAY TECHNOLOGIES

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An American Passive Home

Story & photos by Victor Zaderej

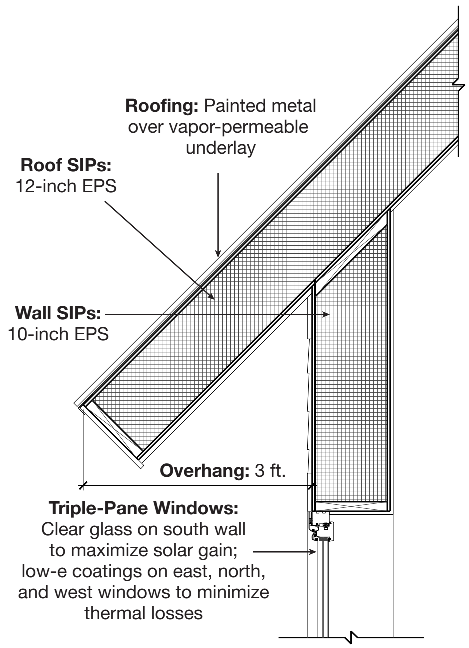
While studying engineering at MIT in the 1980s, I was given an assignment to calculate the cost of building a 2,000-square-foot home that uses 80% less energy to heat and cool than the average home being built at the time. From that assignment many years ago, the results still apply: The cost to *conserve* energy by optimizing insulation, proper passive design, improving the home's thermal envelope, and by using simple but state-of-the-art HVAC systems is one-tenth of the cost to *burn* energy, when calculated over a 30-year "life" of the home.

If we can keep this lesson in mind, we can address a significant portion of our country's energy challenges. This lesson completely changed my outlook on home building, and led me on a 30-year quest to find the most affordable way to build comfortable, energy-efficient homes.

The American passive home (APH) is a building philosophy intended to assimilate the positive aspects of the German Passivhaus standard into a new standard for Americans, achieving the energy-performance standards set by the Germans at a cost that compares to a Prius instead of a Mercedes. APH is based on the following goals and principles:

- Cost-optimize the amount and type of insulation for all surfaces.
- Optimize the type, orientation, and surface area of all windows to take advantage of the solar energy.
- Eliminate or minimize the thermal bridging that often occurs at wall, window, and floor junctions.
- Minimize infiltration losses by using airlock entries, tight wall joints, high-performance windows, and well-sealed doors.
- Create a low-cost geothermal system that helps eliminate the need for a conventional HVAC system and provides continuously filtered fresh air.
- Source North American-made components and materials to reduce the home's overall embodied energy.

Roof Detail



A timber-frame structure, Pura Vida demonstrates an efficient home that looks and feels conventional.

Insulated concrete forms include the support that keeps the forms from being pushed apart during the concrete pour.

Although many of the basic concepts of APH are similar to those used to achieve the German Passivhaus standard, the German standard adheres to an energy-use specification independent of the local climate—and the economics of achieving that standard. For instance, building a home that can be heated with 1 watt of energy per square foot (the approximate Passivhaus standard) in Minnesota is very different than building the same home in Tennessee, since insulating to this specification in Minnesota may be economically impractical. A more affordable strategy would be to use building methods that are commercially available but still achieve a reduction in energy use of between 60% and 80%, or 1 to 2 watts per square foot.

Pure Life

Pura Vida, a common saying in Costa Rica meaning "pure life," is the name of a demonstration home that my wife Polly and I built in Oregon, Illinois, in 2007. It was intended to be an affordable, comfortable, and energy-efficient home—and a showcase for my building design company. Although I feel that homes should be smaller, we built Pura Vida large enough (3,200 sq. ft. plus a 1,300 sq. ft. walk-out basement) to host guests and seminars for those interested in affordable and energy-efficient living. In the past five years, more than 3,500 guests have visited.

Design Process

The first design step was to determine the most cost-effective and commercially available approaches to minimizing energy losses. The insulation techniques that are commonly available in the United States are shown in the "Cost of Insulating" table below.

Cost data and R-value were collected for each of the construction methods, and a "dollar per R" calculated for each. This calculation reveals the lowest-cost, highest-value insulation techniques for the walls, roof, basement walls, and floors.

The next step in the design process was to optimize the amount of insulation based on the temperature difference between the inside of the home and the temperature on the opposite side of the surfaces being insulated. Then, by using the cost per "R" for commercially available insulation systems, the most cost-effective R-value for each exterior surface can be determined. For example, in northern Illinois, given the temperature difference between the inside of the home and the average midwinter temperatures, a roof or wall can be effectively insulated with an R-45 structural insulated panel (SIP). However, using greater levels of insulation requires building techniques that are less cost-

Cost of Insulating

Type	R-Value	Cost per R-Value / $Ft.^2$
XPS (under floor)	R-20	$0.050
Polystyrene SIPs	R-45	0.156
Polyurethane SIPs	R-40	0.175
I-joist, 12 in.	R-36	0.278
Double wall, 6 in.	R-36	0.312
ICF, 8 in.	R-22	0.680

Selected Insulation

Surface	Avg. Winter ∆Temp.	Insulation	R-Value
Roof	45°F	SIP, 12 In.	R-45
Outside walls	40°F	SIP, 10 In.	R-39
Basement walls	30°F	ICF + 4 In. Wall	R-35
Floor	20°F	XPS, 4 In.	R-20

effective or not commercially available in North America. For example, the cost of increasing the R-value of the wall by roughly 20% (R-55) could double the cost of building the walls because SIPs are not commercially available with an R-55 rating and other building techniques are much more expensive per R-value.

Let the Sun Shine In

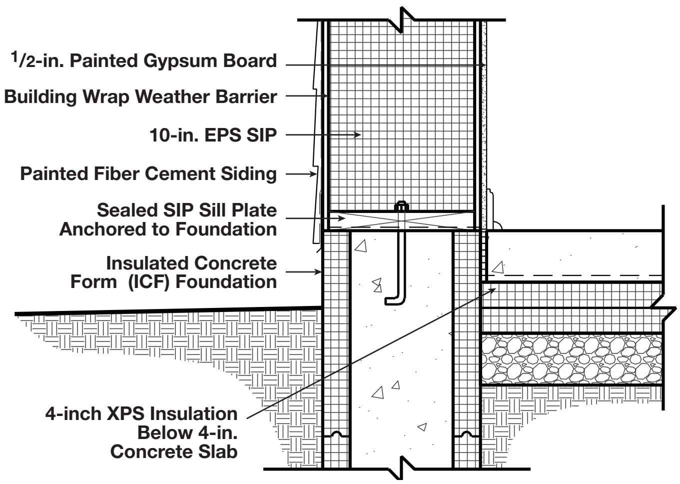
Passive solar homes use the sun's energy to provide significant home heating. It feels almost magical to walk into a 70°F home on a sunny, 0°F day and know that no heating system is operating. Although there is nothing new about harnessing the sun's heat, the materials and design knowledge for capturing solar heat and storing it for night use have improved dramatically in the last 30 years.

We chose Canadian-made Loewen Access, Douglas fir-framed windows, which look and act like awning windows and can be "flipped" to be cleaned from the inside. The windows on the north, east, and west sides are Loewen's Heat Smart III—argon-gas-filled, triple-pane units with two layers of low-e coatings and energy spacers. Because standard low-e coatings are meant to block solar radiation, we specified double-pane Loewen windows with a hard low-e coating and a solar heat gain coefficient of 0.65 for the south-facing windows. I have recently started specifying triple-pane windows without low-e coatings for southern exposures. They cost less than the special-order hard-coat low-e windows and the performance is slightly better.

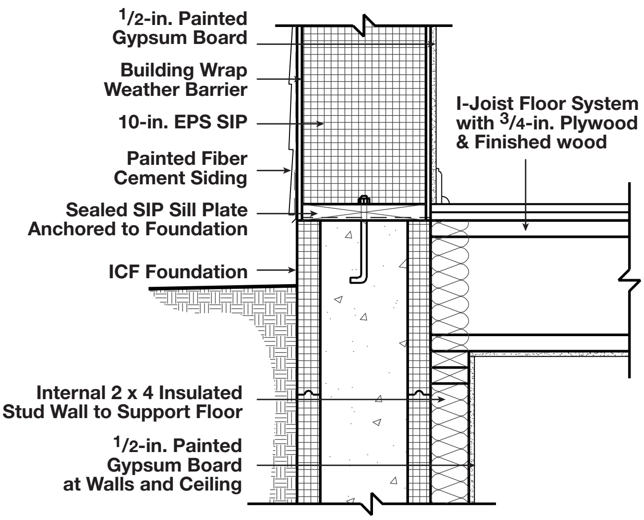
To benefit from passive solar gain, the area of the south-facing windows should be between 10% and 15% of the home's total floor area. Too little glazing means that you

Large south-facing windows, specified for their high solar heat gain coefficient, admit ample sunlight to warm the house on sunny winter days.

Slab-on-Grade Insulation Details



Floor Joist at Basement Wall



won't collect as much energy as you could; too much may result in overheating. Pura Vida's south-facing window area to floor area percentage is 11%.

Reducing Heat Transfer through the Envelope

One of the most important aspects of German Passivhaus design is the level of effort made to eliminate thermal bridging at floor, wall, and roof interfaces. The problem occurs when something without much R-value—like a wall stud—bridges between the inside and outside of the building without intervening insulation. While designing Pura Vida, builder Rick McCanse and I spent many hours discussing the details of how this could be easily—and affordably—accomplished.

Where the floor meets the wall, the 4 inches of extruded polystyrene (R-20) under the 4 inches of poured concrete floor were butted up to the insulated concrete form's (ICF) frost wall. Since the insulation under the concrete was in direct contact with the ICF insulation that extended below the frost line, there was no path for heat loss from the concrete floor.

At the main floor level, an internal 2-by-4 wall was added on the inside of the ICF to increase the R-value of the walls in contact with the earth to R-35 (R-22 from the ICF plus R-13 fiberglass in the stud wall); provide a space to run electrical wiring; and provide floor support that was inside the ICF and SIP's thermal envelope.

Besides thermal bridging compromising a home's efficiency, air leaks can account for 50% of winter energy loss in a typical home. With fewer and easier-to-seal joints, SIPs and ICFs minimize infiltration compared to conventional stud-framed homes. While APHs are built quite tight, infiltration losses can be further reduced by double entries (mud rooms, also known as airlocks). Mud rooms were common in farmhouses, but most modern homes do not include this energy-saving feature. The mud room should be insulated and use a well-insulated, sealed external door and an exterior-quality second door into the interior of the home.

The "earth room" under construction. Once complete, this space will provide a source of free heating and cooling.

Earth Room

In addition to capturing solar gain, Pura Vida takes advantage of another source of free heat (and cooling): from the relatively constant temperature of the ground. In Europe, earth tubes are often buried around the foundation of homes to provide tempered fresh air, but in the United States, there has been concern that earth tubes can grow mold or mildew. With Pura Vida, and subsequent buildings I have designed, an "earth room"—a modified approach to earth tubes—has been successful.

In Pura Vida, the earth room lies below the front porch. A short, 12-inch-diameter tube brings fresh outdoor air into one end of the earth room. The air flows the length of the 48-foot-long room where it is preheated (in the fall and winter) or precooled (spring and summer) through direct contact with the concrete walls prior to entering a heat recovery ventilator (HRV). The earth room is like a large thermal battery, storing heat in the summer for use in the fall and winter and storing "coolness" in the winter for use in the spring and summer. The earth room eliminates the need to use a conventional mechanical heating system for about two months of the year (October and November) and eliminates the need to run a cooling system from mid-May to mid-June. Throughout the rest of year, the earth room significantly reduces the heating and cooling loads.

Buy North American

There are a variety of energy-efficient building products manufactured in Europe, but because of their cost and transport, it is not affordable nor "sustainable" to import them. Buying local was important—not only does the manufacturing process and product assembly contain significant amounts of embedded energy, but the transportation of materials from remote locations can add significantly to a building's total energy content. All of the critical components used to build Pura Vida were manufactured in North America.

A 4.5 kW Marathon water heater (right) provides hot water to the heat-exchanger coils within the all-in-one Enerboss (left), a heating, filtration, and heat-recovery ventilation system.

After passing through the earth room, the air enters the Nu-Air Ventilation Enerboss, a complete heating, filtration, and HRV system. An efficient fan constantly pulls air from the bathrooms and kitchen, which is exhausted, while the same amount of fresh air is evenly distributed throughout the home by an airflow-balanced high-velocity duct system. The system has operated flawlessly for the past five years. The Enerboss system requires an external source of hot water for heating the air to be distributed. In Pura Vida, we use a 4.5 kW Marathon water heater to provide hot water to the heat exchanger coils within the Enerboss. Air conditioning is provided by a 3-ton, 16 SEER Lennox Elite. The evaporator for the AC unit is mounted on top of the Enerboss.

An air-to-water heat pump provides domestic hot water.

Visitors to Pura Vida often comment how fresh the air is and how quiet it is within the home. The comfort provided by constantly filtered fresh air moving throughout the home makes it difficult to go back to living with a conventional HVAC system.

Domestic Hot Water

A small Nyle Systems air-to-water heat pump mounted on a wall in the earth room provides domestic water heating. A timer is programmed to turn it on in the evenings when the time-of-use electricity price is $0.02 to $0.03 per kWh. The hot water is stored in a well-insulated 105-gallon Marathon water heater for use during the day. The average monthly cost for domestic hot water is about $5. (The timer is bypassed when we have guests or need to use more hot water.)

We also have a GFX Technologies wastewater-to-water heat exchanger. Although the concept of recovering the energy in hot water going down the drain is an interesting one, the high cost of copper makes this technology too expensive to be cost-effective for the amount of preheated water the unit provides.

Demonstrated Performance

Six Lascar temperature and humidity sensors were placed throughout the home, outside, and in the earth room. Data collected from these sensors every 30 minutes for the past five years—along with energy use data collected from several TED (The Energy Detective) units and our utility bills—have validated the home's performance.

The all-electric home's advantage is that we can measure and directly compare the energy use for every appliance and system. Having collected data on the efficiency of the air-to-water heat pump in the earth room for providing domestic hot water, I plan to modify the heating system to include a second heat pump, instead of the existing water heater, for space heating. This should reduce the electricity demand for space heating by at least 60%.

When the home was built, we also decided to sign up for time-of-use utility metering. This utility billing method provides us with cheaper energy during off-peak times, and more expensive energy during peak times. The risk we took with this decision was that if we needed to use large amounts of energy during peak times—like running air conditioning midday during the summer—the cost could be significantly higher. The table (upper right) shows our average annual energy use for the various portions of the property along with an approximate annual cost for each.

Average Annual Energy Use & Cost

Item	Annual Usage (kWh)	kWh per Ft.^{2} (4,500 ft.^{2})	German Passivhaus Standard (kWh per ft.^{2})*	Cost
Space heating	6,700	1.49	1.39	$450
Cooking, refrigeration, lighting, air handling, entertainment systems, washer & dryer	3,500	0.78	0.60	200
Domestic water heating	2,500	0.56	0.33	60
Air conditioning & dehumidification	2,000	0.44	1.39	200
Well pump	1,500	n/a	n/a	100
Barn lighting & heating	1,500	n/a	n/a	100
Totals	**17,700**	**3.27**	**3.71**	**$1,110**

*The German standard does not differentiate in the same way as the table, so 0.93 kWh per sq. ft. per year is divided up somewhat arbitrarily between the "Cooking..." and "DWH" rows.

Because of the relatively high upfront cost of renewable electricity systems, we felt it was important to first design and build a home that is as efficient as possible—and then get a good understanding of the home's energy demands. A year after the home was completed, we applied for and received a state grant to measure the effectiveness of residential small wind systems.

A small wind-electric generator offsets a small portion of the home's electricity use. It would produce much more on a tower tall enough to clear all obstructions in the area.

We installed a 2.4 kW Southwest Windpower Skystream 3.7 turbine on a 60-foot tower (at the time, we did not understand that height is too short for nearly *all* applications). The utility account was converted to net metering so that we could sell our excess energy back to Commonwealth Edison. The energy production from the Skystream was monitored through a Zigbee data system and logged on a computer.

We believed we had a wind resource that was sufficient to justify a wind-electric system. Our chosen turbine, the Skystream, is predicted to produce about 2,600 kWh per year given an 11 mph resource, and about 900 kWh per year in 8 mph winds. After several years of operation, the system has produced roughly 500 kWh per year, or the equivalent of $50 of energy, which is expensive electricity when you consider the $21,000 installation cost.

It is clear now that the information we started with was not sufficient to justify using wind energy at our site. Factors contributing to our turbine's lower-than-anticipated production include a tree line that sits about 800 feet to the west, resulting in turbulent wind from the prevailing wind direction. A taller tower would undoubtedly help with this problem, because the farther you get away from the earth and its obstructions, the more wind there is. As a well-known small-wind expert has said, we unknowingly chose expensive energy over an expensive tower.

Over the past several years, the cost of photovoltaic systems has come down dramatically. During that time, we collected information on the energy demand for Pura Vida. We found that during the fall and spring, when there was no energy use for heating or cooling, the average demand was between 600 and 700 kWh per month.

In 2011, we installed a 4.3 kW grid-tied PV system that should average about 400 kWh per month. Twenty-four batteries provide backup for power outages and provide enough energy to live without the grid periodically—assuming that the backup heating would be provided by the wood heater instead of electricity. Performance data is being collected by the OutBack MATE3 energy monitor and we should have an accurate performance picture by the end of 2012.

Two pole-mounted PV arrays offset about 27% of the home's electricity use.

Future of APH

We believe that building super-energy-efficient homes will have a significant impact on U.S. energy use. If the building cost of an APH is within 15% of a conventional building method, a conservative energy cost savings estimate is more than $1,000 each year per home.

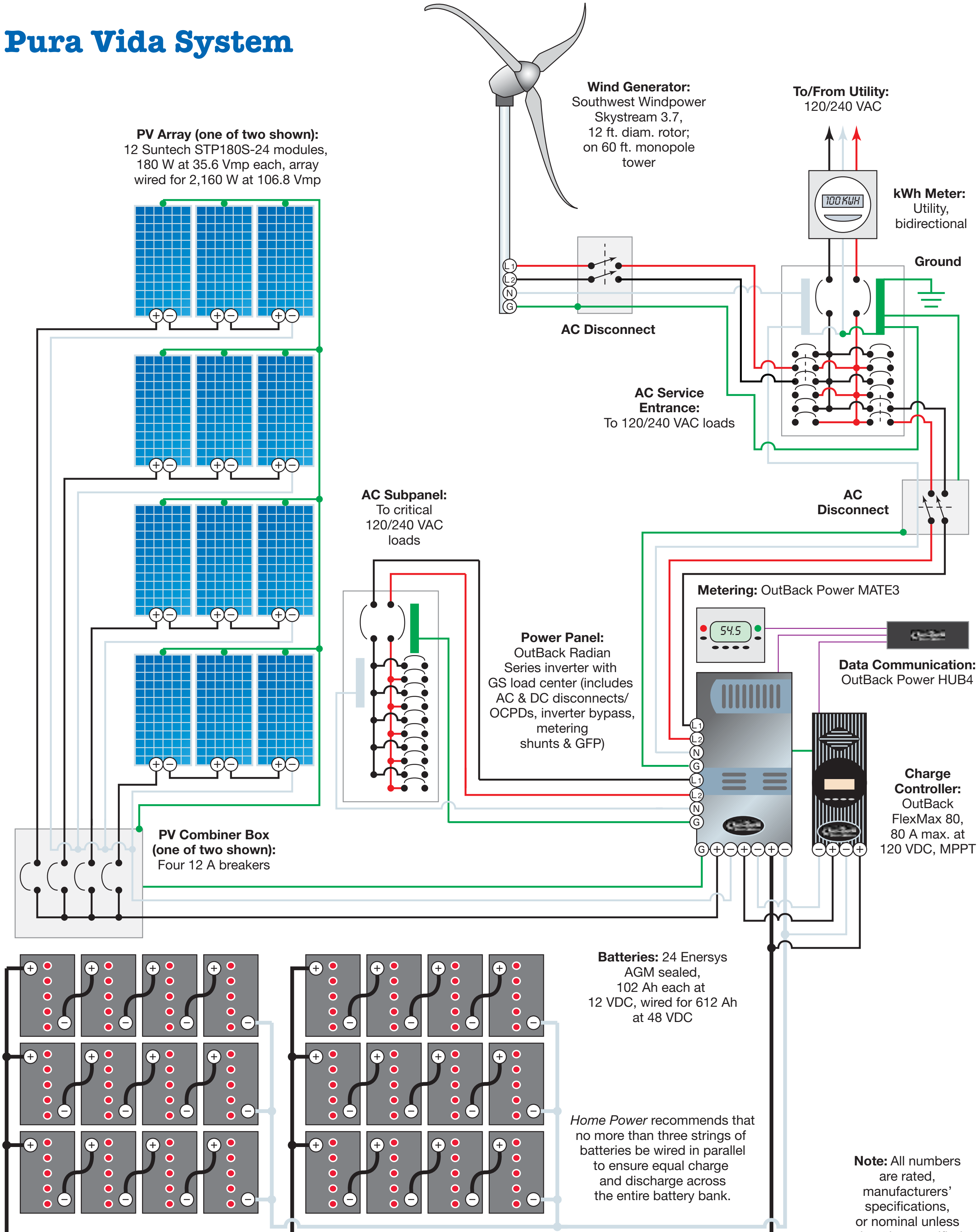
One outcome of the recent economic downturn has been that the American consciousness has been awakened to the importance of common-sense solutions to important challenges. For families paying to heat and cool their homes—and as a nation that needs to use less fossil fuel—emphasizing energy efficiency in homebuilding is a simple yet promising way to address these challenges.

A battery bank provides backup power in the event of a utility outage.

An OutBack MATE3 keeps tabs on the RE system.

This OutBack Radian series inverter and load center also serves as an AC and DC enclosure. The system's charge controller sits to the right.

Pura Vida System



Tech Specs: Hybrid PV/Wind System

Overview

System type: Battery-based grid-tied PV & wind-electric

System location: Oregon, Illinois

Solar resource: 4.5 average daily peak sun-hours

Yearly Production: 4,800 AC kWh (PV); 500 AC kWh (wind)

Utility electricity offset: 27% (PV); 3% (wind)

Photovoltaics

Modules: 24 Suntech STP180S-24, 180 W STC, 35.6 Vmp, 44.4 Voc, 5.05 Imp, 5.4 Isc

Array #1 (two identical arrays): Four three-module series strings, 2,160 W STC total, 106.8 Vmp, 133.2 Voc

Array combiner box: MidNite Solar with 12 A breakers

Array disconnect: Breaker (in power panel)

Array installation: DPW Power-Fab top-of-pole mounts; arrays set at a 28° to 40° tilt

Wind Turbine & Tower

Turbine: Southwest Windpower Skystream 3.7

Rotor diameter: 12 ft.

Rated energy output: 268 kWh/month at 12 mph ave.

Tower: 60 ft. Southwest, freestanding monopole

Balance of System

Charge controller: OutBack FlexMax 80, 80 A, MPPT, 150 VDC maximum input voltage, 48 nominal output voltage

Inverter: OutBack Power GS8048, 48 VDC nominal input, 120/240 VAC output (PV); Built-in, 240 VAC output (wind)

System performance metering: OutBack MATE3 (PV); SkyView (wind)

Energy Storage

Batteries: 24 Enersys sealed AGM, 12 VDC nominal, 102 Ah at 20-hour rate

Battery bank: 48 VDC nominal, 612 Ah total

Battery/inverter disconnect: 175 A breaker

Wood floors and exposed posts and beams lend warmth and beauty to this efficient home.

Access

Victor Zaderej (zaderej@alum.mit.edu) has been passionate about energy use in homes, businesses, and transportation for 30 years. He holds two engineering degrees from MIT, and an MBA. Through his company, Solar Homes, he helps design energy-efficient buildings. He is currently the manager of Advanced Solid State Lighting at Molex.

Solar Homes • solarhomesus.com • Green building design

McCanse Builders • mccansebuilders.com • Builder

Pura Vida Systems:
EnerSys • enersys.com • Batteries

Nu-Air Ventilation • nu-airventilation.com • Heating, cooling & heat recovery system

Nyle Systems • nyle.com • DHW heat pump

OutBack Power • outbackpower.com • Inverter & charge controller system

Southwest Windpower • windenergy.com • Wind generator

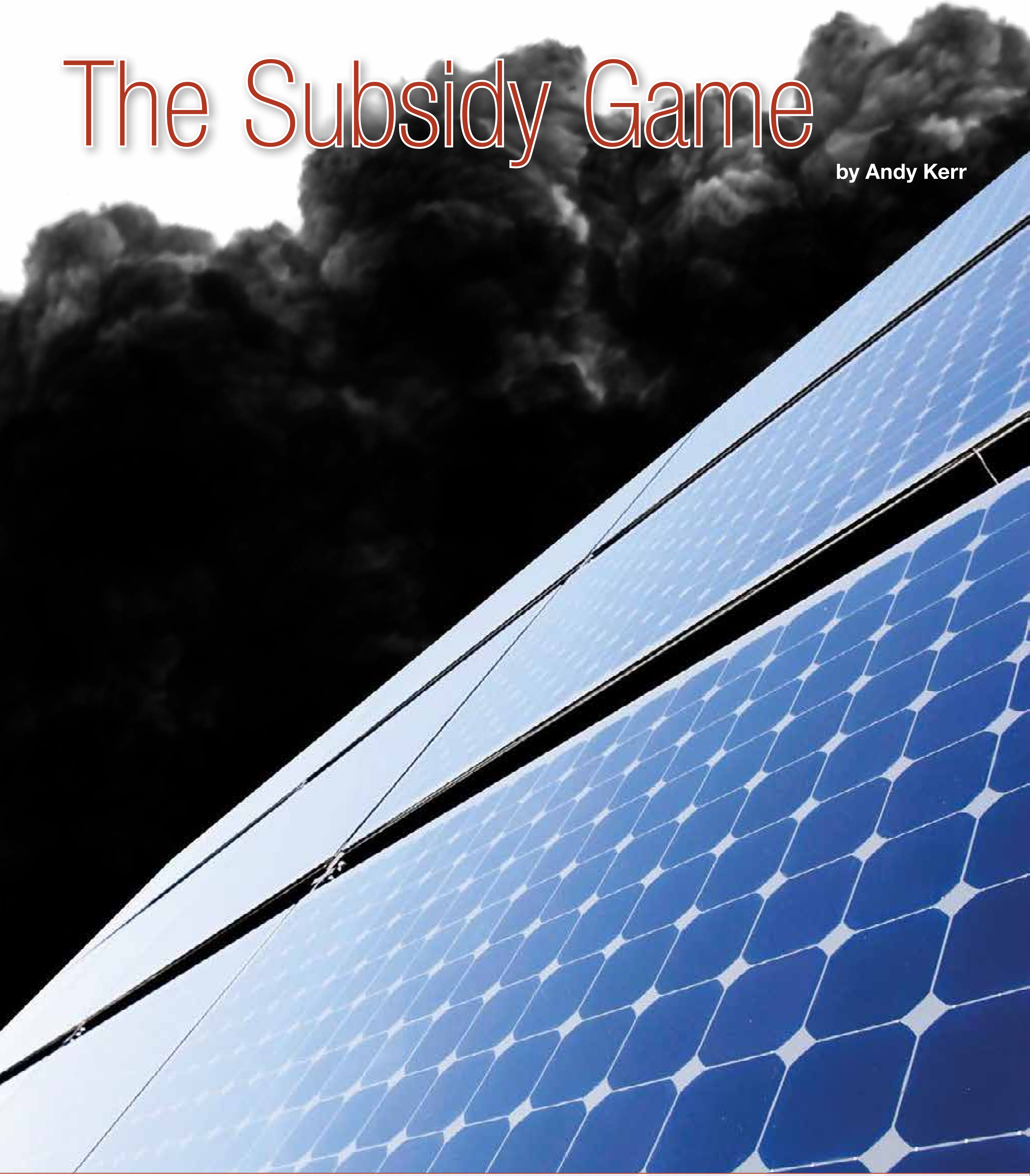
Suntech • am.suntech-power.com • PV modules

WaterFilm Energy • gfxtechnology.com • Wastewater heat recovery

Water Heater Innovations • marathonheaters.com • Hot water storage

The Subsidy Game

by Andy Kerr



Most examinations of government energy subsidies don't factor in what economists call "externalities," side effects or consequences of activities that affect other parties without being reflected in the costs involved. With energy production, some of the biggest externalities are the social, health, and environmental effects of pollution.

The question is not whether fossil fuel, nuclear, and renewable energy industries are government subsidized, but how much, how equitably, and at what cost to the environment, and to taxpayers' pocketbooks and health.

The ostensible purpose for government subsidies is to achieve social goods and services that the private sector is unwilling or unable to provide. The political purpose may or may not be the same.

Subsidies are necessary because the social good or service desired might not be profitable to a business. The federal government has subsidized industries and facilities since its inception. The dredging of ports, giving away millions of acres of land to get railroads built, and the home mortgage interest deduction are all government subsidies.

Government subsidies may take several forms, including the funding of basic research. For instance, we wouldn't have PV modules on earth if not for NASA needing them in space. Most libraries and airports are government-run, which is a subsidy to private citizens or private industry. Subsidies can also be grants, tax breaks, or tariffs on foreign goods to protect domestic manufacturers.

Of course, when there is not general agreement on the worthiness of a subsidy, such as public libraries, one person's wasteful government subsidy is another's wise government investment. Whether government subsidies make sense depends upon the subsidy and on ideology. Should government be picking winners and losers?

Energy Subsidies: How Much To Whom?

As to which energy sources are being subsidized and by how much is a matter of perspective. Below, some of the most recent critiques are surveyed. Collectively considering all of them results in relatively good comparison of subsidies between various energy sources.

A report prepared for the nuclear industry by Management Information Services (MIS), an economic research and management consultancy, analyzed federal energy incentives (aka subsidies) to the oil, natural gas, coal, hydroelectric, nuclear, renewables (primarily wind and solar), and geothermal industries over the past 60 years (see "Summary" table). They identify six categories of subsidies:

Tax policy includes special credits, deductions, allowances, and exemptions available only to a particular energy industry. As examples, wind and solar get tax credits, while the oil and gas industry receives special allowances—such as more rapid depreciation for tax purposes than is allowed for other industries—for resource depletion and intangible drilling costs.

Regulation includes "gains realized by energy businesses when they are exempt from federal requirements that raise cost or limit prices" and "costs of federal regulation that are borne by the general budget and not covered by fees charged to regulated industries." The nuclear power industry couldn't afford to pay the insurance premiums needed in the event of an accident, so the federal government relieves them of the obligation.

Research and development is also for demonstration programs. Neither the nuclear or solar industries would have gotten off the ground as they did without federally funded research. Perhaps PV modules would have come about by private firms seeking profit that would have been available had fossil fuels not been subsidized, but perhaps not—and certainly not as early as fossil fuels did.

Market activity "includes direct federal government involvement in the marketplace." Safety airbags in automobiles became commonplace after the federal government required them for its own fleets.

Government services include "all services traditionally and historically provided by the federal government without direct charge." For example, infrastructure investments like the deepening of ports for bigger ships to haul coal, oil, or liquefied natural gas.

Disbursements "are direct financial subsidies such as grants." (In the table, the negative number in this column for the nuclear industry represents a $18 billion surplus due to the nuclear industry having paid into a fund for waste disposal that hasn't been tapped.) A huge flaw in the Management Information Services (MIS) methodology for evaluating federal energy incentives for nuclear power—and therefore the numbers—is the way it accounts for the $16 billion that the nuclear power industry has paid into a federal fund to help pay for permanent waste storage. As the federal government has yet to open a high-level nuclear waste repository, MIS treats this number as a subsidy to the federal government from the nuclear power industry. However, the current estimated cost to build and operate such a facility at Yucca Mountain, Nevada, is $96.2 billion. That facility has been built, but has not yet received a license to operate, due to safety concerns.

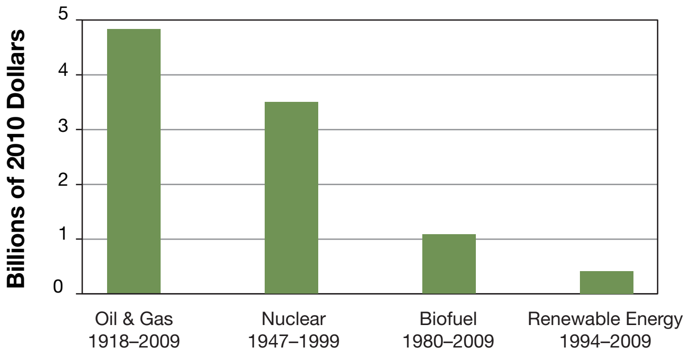
Summary of Federal Energy Incentives, 1950-2010

Energy Source (Data in Billions of 2010 Dollars)

Incentive	Oil	Gas	Coal	Hydro	Nuclear	RE	Geothermal
Tax policy	$194	$106	$35	$13	—	$44	$2
Regulation	125	4	8	5	16	—	—
R & D	8	7	36	2	74	24	4
Market activity	6	2	3	66	—	2	2
Government services	34	2	16	2	2	2	—
Disbursements	1	—	7	2	-18	2	—
Total	$368	$121	$105	$90	$74	$74	$8
Share	44%	14%	12%	11%	9%	9%	1%

Source: *60 Years of Energy Incentives: Analysis of Federal Expenditures for Energy Development*, a report prepared for the nuclear industry

Historical Annual Average Energy Subsidies



Source: *What Would Jefferson Do: The Historical Role of Federal Subsidies in Shaping America's Energy Future.* (Research limitations resulted in the analysis for nuclear energy ending in 1990. The authors say that if they had assumed 1990s-level subsidies extended through the 2000s, that the annual average would only be slightly more.)

Even though this study was funded by the nuclear power industry, the report's evaluation of other energy sources is generally credible. Other analysts have come up with similar results. Nancy Pfund is with DBL Investors, a venture capital firm that specializes in investing in solar and energy-efficiency companies. Although she's not a disinterested analyst of energy subsidies, Pfund's analysis is well worth considering. As the graph (above) shows, the older the industry, the greater the subsidies.

Government subsidies to the coal industry began earlier than the rest and continue to this day. However, Pfund's analysis focused on government subsidies of various energy sectors during their early days. The farther back in time, though, the harder it is to obtain actual numbers. "Suffice it to say, domestic coal did not arrive on the scene as a mature, low-cost, and competitive fuel source. Rather, government support over many years helped to turn it from a local curiosity in Schuylkill County, Pennsylvania, into the dominant fuel source of its time," says Pfund.

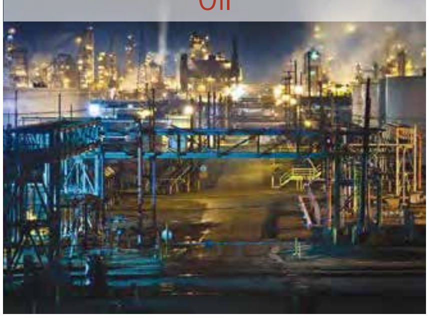
In her report, Pfund shows that the oil and gas and nuclear industries were subsidized far more during their early development—both in real dollars and as a percentage of the federal budget—than wind and solar. Cumulatively, oil and gas has received $447 billion since 1918; nuclear, $185 billion since 1947; biofuels, $32 billion since 1980; and other renewables, $6 billion since 1994 (all in 2010 dollars).

In a 2010 study, the Tax Foundation, a nonpartisan educational organization that lies on the conservative end of the political spectrum, could only manage to find fossil fuel subsidies of $2.8 billion per year, while "green energy" subsidies were found to be $11.3 billion per year. The Foundation's main point is that the American oil companies pay way more taxes than they receive in subsidies. True, as often they have huge profits. In the first half of 2011, the six largest companies (aka "Big Oil") had profits that totaled $88.1 billion. Of course, the taxes they pay are supposed to be their fair share for the government services that all of us receive; it's not supposed to be the mere moving of nickels from one corporate pocket to another.

However, as a July 3, 2010, article in *The New York Times* noted, "an examination of the American tax code indicates that oil production is among the most heavily subsidized businesses, with tax breaks available at virtually every stage of the exploration and extraction process." It continues:

> *According to the most recent study by the Congressional Budget Office, released in 2005, capital investments like oil field leases and drilling equipment are taxed at an effective rate of 9%, significantly lower than the overall rate of 25% for businesses in general and lower than virtually any other industry.*
>
> *…for many small and midsize oil companies, the tax on capital investments is so low that it is more than eliminated by various credits. These companies' returns on those investments are often higher after taxes than before.*

Oil



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Natural Gas

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The federal government has subsidized industries and facilities since its inception. The dredging of ports, giving away millions of acres of land to get railroads built, and the home mortgage interest deduction are all government subsidies.

Whether government subsidies make sense depends upon the subsidy and on ideology. Should government be picking winners and losers?

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This is another way of saying that not only did such companies pay no taxes, they actually made profits from the government.

The Price We Pay for Energy

Most examinations of government energy subsidies don't factor in what economists call "externalities," side effects or consequences of activities that affect other parties without being reflected in the costs involved. With energy production, some of the biggest externalities are the social, health, and environmental effects of pollution.

Externalities can be difficult to quantify, especially when it comes to energy. However, according to the National Academy of Sciences' July 2011 "Report to the President/ Sustaining Environmental Capital":

> *Just the damages from [fossil fuel energy's] external effects [that] the committee was able to quantify add up to more than $120 billion for the year 2005. (These are damages related principally to emissions of [oxides of nitrogen, sulfur dioxide, and particulates] relative to a baseline of zero emissions from energy-related sources for the effects considered in this study.) Although large uncertainties are associated with the committee's estimates, there is little doubt that this aggregate total substantially underestimates the damages, because it does not include many other kinds of damages that could not be quantified for reasons explained in the report, such as damages related to some pollutants, climate change, ecosystems, infrastructure, and security.*

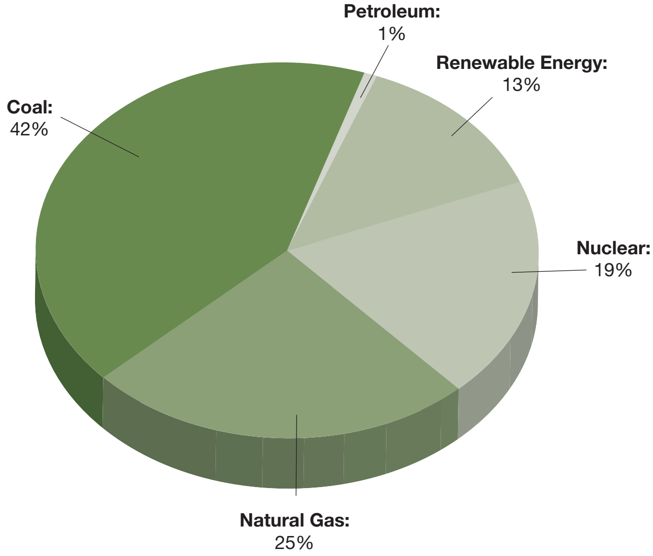
Soil, air, and water pollution—and its effects on human and environmental health—costs our society significantly. Besides not assessing fees for polluting industries' externalities, the federal government also shields certain energy generation from liability. The *Green Scissors 2011* report, promoting federal environmental and fiscal responsibility, notes that:

> *…the Oil Pollution Act of 1990 caps industry liability for offshore drilling accidents at a paltry $75 million, but they can cost taxpayers billions of dollars. The cleanup of the British Petroleum's 2010 Deepwater Horizon spill in the Gulf of Mexico has already topped $6.8 billion, which has been paid for by the federal and state governments.*

Nor do most examinations of government energy subsidies factor in national security costs. In *Reinventing Fire: Bold Business Solutions for the New Energy Era*, energy-efficiency expert Amory Lovins examines the true costs of the nation's addiction to oil, some of which can easily be considered industry subsidies.

- "Of America's $0.9 trillion oil bill in 2008, $388 billion went abroad. Some of this money paid for state-sponsored violence, weapons of mass destruction, and terrorism.
- "In 2010, a Princeton study pegged the cost of U.S. forces just in the Persian Gulf in just one year (2007) at half a trillion dollars, or about three-fourths of the nation's total military expenditures. That's similar to the peak expenditure rate for the Cold War. It is also about 10 times what the U.S. typically pays for all the oil it imports from the Persian Gulf.

Sources of U.S. Electricity Generation, 2011



- "[T]he economic costs of oil dependence, plus U.S. military expenditures for Persian Gulf forces (and minus the cost of the oil itself), total roughly $1.5 trillion a year, or 12% of GDP—far more than our total annual energy bill."

Was the Iraq War about oil? Former Defense Secretary Donald Rumsfeld said the U.S. invasion of Iraq had "nothing to do about oil." Yet former Federal Reserve Chairman Alan Greenspan, writing in his memoir, said, "It is politically inconvenient to acknowledge what everyone knows. The Iraq War is largely about oil."

Nobel economist Joseph Stiglitz of Columbia University and Harvard University budget expert Linda Bilmes estimate the eventual cost of the Iraq War at $4 to $6 trillion. For perspective, the recent U.S. financial bailout cost $4.6 to $8.7 trillion. Even adjusted for inflation, World War II cost a mere $3.6 trillion.

The cost of America's oil addiction can also be measured in human lives. As of May 29, 2012, 4,409 U.S. troops have been killed and nearly 32,000 wounded. Not to mention the approximately 655,000 Iraqi fatalities, according to *The Lancet*, a British medical journal.

Not a Level Playing Field

Many direct government subsidies for the coal, oil and gas, and nuclear industries are buried deep in permanent provisions of the U.S. tax code. Once embedded, a provision of law is hard to remove. In contrast, most government subsidies for wind and solar come in the form of short-term provisions that expire after a period of time. The wind and solar lobby, which is far smaller than the lobby machine for Big Oil, has to continuously use its resources to seek extensions to renewable tax credits. With the financial and political states of the nation, the best they can do is get extensions to last just a few years. Meanwhile, the fossil fuel and nuclear industries can lobby to maintain the status quo and be successful.

Certain industries, such as pipeline operators, drillers, and mine operators, can organize themselves under a master limited partnership, which pays no corporate tax. Any tax liability passes directly to investors, who pay the lower capital gains rate (which is lower than most income tax rates). Solar and wind companies cannot do the same.

Good Government Policy or Not?

If fossil and nuclear fuel prices reflected their true costs to human health, the environment, and economic growth, there wouldn't be such industries—the energy they produce would be too expensive.

Government subsidies either create markets or industries, or correct market failures. It is ultimately a political question of whether society needs a missing industry or that a market needs correcting.

Getting Good Government Policy

Leveling the playing field so renewable energy can fairly compete with nonrenewable energy can be done in basically three ways. Implementing each approach comes with its own set of political challenges.

- **Increase renewable energy subsidies to be commensurate with nonrenewable energy subsidies.** If you can't beat 'em, join 'em. Of course, in these fiscal times, getting more grants, tax credits, or tax breaks is difficult.
- **Eliminate all government subsidies to all forms of energy.** If oil, gas, coal, and nuclear energy were not subsidized, renewable energy sources wouldn't need any subsidies, either. Clean and safe energy would dominate the market. However, while it's hard to *get* a government subsidy, it's even harder to *get rid of* one.
- **Internalize externalities.** If the fossil fuel industry had to pay for its pollution of the environment and its harm to human health, its product would be so expensive that renewable energy resources would have the wind at their back on the sunny side of the street. Eventually, Big Tobacco was held accountable; maybe Big Oil will be, too.

While every president since Richard Nixon has called for energy independence, the United States is still reliant on foreign oil. According to the Energy Information Administration, the

Air Photo Service Co. Ltd., Japan

iStockPhoto.com/FernandoAH

Most government subsidies for wind and solar come in the form of short-term provisions that expire after a period of time. The wind and solar lobby, which is far smaller than the lobby machine for Big Oil, has to continuously use its resources to seek extensions to renewable tax credits.

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United States imports about 49% of its petroleum supply. In his 2006 State of the Union address to Congress, President George W. Bush said, "America is addicted to oil."

Yet at this writing, Iran is threatening to close the Straight of Hormuz, a navigational chokepoint through which 20% of the world's annual oil production must pass. The United States says it will not allow any restriction of oil moving from the Persian Gulf. The downside of this conflict is the threat of war. The upside is that oil prices are rising, and higher oil prices make renewable energy options more attractive.

Positive Trends

The good news is that even if the U.S. energy playing field is not leveled, the *trends* for renewables are headed in the right direction, while the trends for the fossil fuels and nuclear energy industries are going in the wrong direction (for those industries, but not for those who breathe air and drink water and/or pay taxes).

In the United States, many coal power plants are shutting down because it's too expensive to make upgrades to meet requirements of the Clean Air Act. Of course, much of this demand for energy may move to natural gas, rather than renewables. But natural gas faces a more problematic future, as public concerns increase about the environmental costs of obtaining gas trapped in shale—a practice known as hydraulic fracturing, or "fracking," where a mixture of chemicals, sand, and water are injected into bedrock to release pockets of natural gas. This practice has been linked to chemical contamination of water supplies and low-level earthquakes. In contrast, PV modules and wind generators provide green, sustainable electricity without air, soil, or water pollution.

In general, the trend has long been—and, in all likelihood, will continue to be—that the cost of renewable energy will continue to decrease, while the cost for nonrenewables will continue to increase.

Access

Politically, Andy Kerr is a flexitarian who—depending upon the circumstances—favors markets and market-based solutions, government regulation, social group coercion, and/or individual voluntary action. He splits his time between Ashland, Oregon, and Washington, DC, and may be reached at andykerr@andykerr.net.

Resources:

Fossil Fuel Subsidies: A Closer Look at Tax Breaks, Special Accounting, and Societal Costs • tinyurl.com/homepower1

What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America's Energy Future • tinyurl.com/homepower2

Subsidy Gusher: Taxpayers Stuck With Massive Subsidies While Oil and Gas Profits Soar • tinyurl.com/homepower3

Green Scissors: Cutting Wasteful and Environmentally Harmful Spending • tinyurl.com/homepower4

Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. Washington, DC: The National Academies Press. • http://tinyurl.com/homepower5

60 Years of Energy Incentives: Analysis of Federal Expenditures for Energy Development. Management Information Services, Washington, DC.• http://tinyurl.com/homepower6

Choosing an Inverter

by Lena Wilensky

An inverter's job is straightforward—change PV-generated or battery-stored DC electricity into AC electricity that can be used by household appliances or sent back to the utility grid. However, with a plethora of models and options, shopping for an inverter has become a more complex task. With some basic know-how, you can narrow down the choices to select the right one for your application.

The most basic choices are whether your system will be grid-tied or off-grid, and whether your system will include batteries, either for off-grid use or on-grid with battery backup. Inverters are specific to each.

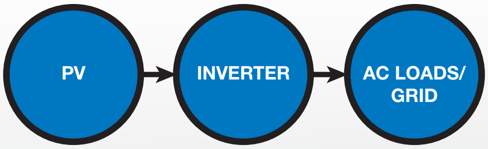
Got Batteries?

Grid-tied systems are the most common PV systems in the United States. Most do not use batteries; the energy from the PV array is sent straight through the inverter to the AC loads or the utility grid. There are more brands and models of batteryless grid-tied inverters on the market than any other inverter type.

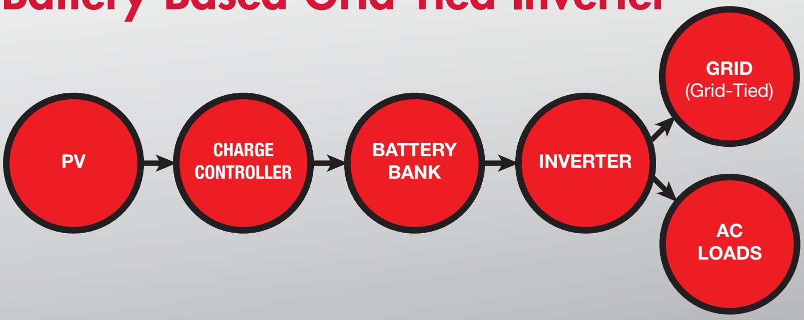
When there are batteries in a PV system, an entirely different type of inverter must be used. Off-grid (stand-alone) systems use batteries for energy storage. Inverters for these can be divided into two categories, based on some of their features. Larger battery-based inverters have a wide range of programmable features and options, and are designed to run a whole house's loads, as well as regulate and charge the battery bank from an AC power source. Smaller battery-based inverters tend to be much simpler, don't include AC battery chargers or battery monitoring, and are used predominantly in applications where there are only a few AC loads.

Grid-tied systems with battery backup can send excess energy to the grid, but when the grid is unavailable, will still energize loads using energy stored in the batteries. While many battery backup grid-tied inverters can be used for off-grid applications, the inverse is not the case—most off-grid inverters cannot interconnect with the grid.

Batteryless Grid-Tied Inverter



Battery-Based Grid-Tied Inverter



Shopping for a Grid-Tied Inverter

AC Output Power. First, match the inverter's *AC output power* to your PV array. A PV array's standard test conditions (STC) power rating will give you a good idea of the minimum size of inverter needed. For example, a 5 kW PV array will need an inverter with about a 5 kW power output. If the climate is such that the array never reaches STC power—such as in warmer sea-level climates—you may be able to "undersize" your inverter by 10% to 20%. In our example, undersizing would call for a 4 to 4.5 kW inverter for that 5 kW PV array. Arrays in colder, sunnier areas, such as at higher elevations, may necessitate "oversizing" the inverter to avoid power clipping—when the inverter cuts off some of the PV power because it can't produce more than its rated power. There's no danger in choosing an inverter with a larger power output, and the price difference for a slightly larger inverter is usually small. Additionally, a larger inverter can capture intermittent

power-one.com

With maximum power point tracking (MPPT) for two separate series strings, the Aurora Power One grid-tied inverter can accommodate two subarrays with different orientations or nominal voltages.

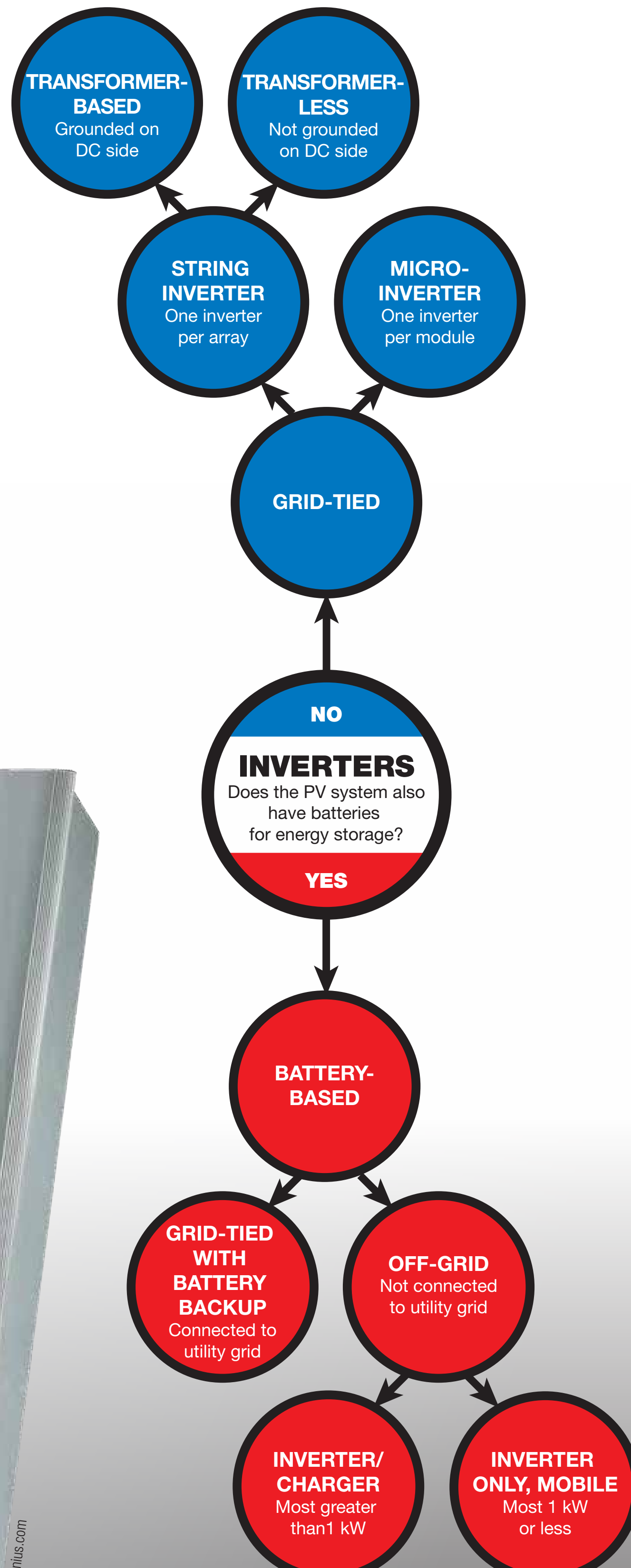

sma-america.com

The SMA America Sunny Boy 700 is the smallest of the available grid-tied string inverters.

fronius.com

The Fronius IG+ 11.4 is one of the largest residential grid-tied inverters.

Batteryless vs. Battery-Based



Example Specifications

	1.8 kW	2.5 kW
DC Input		
Absolute Max. Input Voltage	400 VDC	
MPPT Input Voltage Range	125-350 VDC	
Max. Operating Input Current	11 A	15 A
AC Output		
Nominal Output Voltage	208 or 240 VAC, One-Phase	
AC Voltage Range (Standard)	-12%/+10%	
Continuous Output Power (280/240 VAC)	1,800 W	2,500 W
Continuous Output Current (208 VAC)	8.7 A	12 A
Continuous Output Current (240 VAC)	7.5 A	10.4 A
Max. Backfeed Current	0 A	
Nominal Output Frequency	59.3-60.5 Hz	
Power Factor	Unity, >0.99	
Total Harmonic Distortion (THD)	<4%	
Efficiency		
Peak Efficiency (208/240 VAC)	94.5%	94.5%
CEC Efficiency (208 VAC)	92.5%	92.0%
CEC Efficiency (240 VAC)	92.5%	93.0%
Tare Loss (208 VAC)	0.26 W	0.10 W
Tare Loss (240 VAC)	0.14 W	0.32 W
Temperature		
Ambient Temp. (full power)	-13°F to +131°F (-25°C to 55°C)	
Storage Temperature Range	-13°F to +131°F (-25°C to 55°C)	
Relative Humidity (non-condensing)	5%-95%	
Monitoring Options		
Web-based Monitoring (Inverter-Direct)	Available	
Revenue Grade Monitoring	External	
Third-Party Compatibility	Standard via RS485	
Safety Listings & Certifications	UL 1741/IEEE 1547, IEEE 62.41.2 C1 & C3, FCC part 15 A & B	
Testing Agency	TUV	
Warranty		
Standard	5 year	
Optional	10 year	
Enclosure		
Transformer	Standard, fully-integrated (internal)	
AC/DC Disconnects	Optional with integrated panel	
Dimensions (H x W x D)	18.5 in. x 13.1 in. x 5.6 in. (470 mm x 333 mm x 143 mm)	23.6 in. x 13.1 in. x 5.6 in. (600 mm x 333 mm x 143 mm)
Weight	34.1 lbs. (15.5 kg)	36.3 lbs. (16.5 kg)
Enclosure Rating	NEMA 4X	
Enclosure Finish	Anodized aluminum	

moments of high PV output, such as those stemming from cold, sunny days or from "edge-of-cloud" effect—and possibly leave room for future expansion (see "Ask the Experts: Sizing Inverters for Cloud-Edge Enhancement" in *HP143*).

DC Voltage Input Window. This is the voltage range that the inverter will accept from the PV array. Input voltage for U.S. residential inverters will never be above 600 VDC, and some models will have considerably lower values. Since cold temperatures increase PV array voltage, and high temperatures decrease it, temperature coefficients and local climate data will determine the highest and lowest expected voltages. Exceeding an inverter's maximum voltage specification may cause inverter damage or worse (fire), and while not dangerous, array voltage that's too low can cause the inverter to stop processing power.

Most grid-tied inverter manufacturers offer online string-sizing programs that allow you to select specific PV modules, and input minimum and maximum ambient temperatures. The program will display how many modules can be connected in series to fit a particular inverter's DC voltage window (see the "Online String Sizing" sidebar).

Maximum Power Point Tracking (MPPT). All grid-tied inverters employ some kind of MPPT, which optimizes the power output of the PV array. Most inverters will simply follow one MPP for the entire array as it changes throughout the day, but some models can follow two series-string MPPs for a slightly better energy harvest for arrays with multiple orientations. Microinverters, AC modules, and DC optimizers all offer the ability to track individual module MPPs (discussed later).

Advanced Energy's PV Powered inverter has integrated AC and DC disconnects.

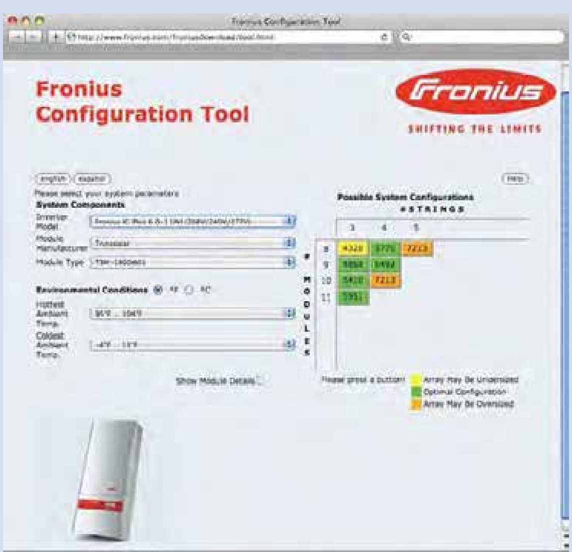
Online String-Sizing

Most inverter manufacturers offer Web-based system configuration tools to help determine the number of specific modules that can be connected to a particular inverter. You input the PV module model, inverter model, and high and low ambient temperatures for your area, and it provides you with different possible configurations you can use—the number of modules in series, and the number of series strings in parallel—to match the inverter's specifications.

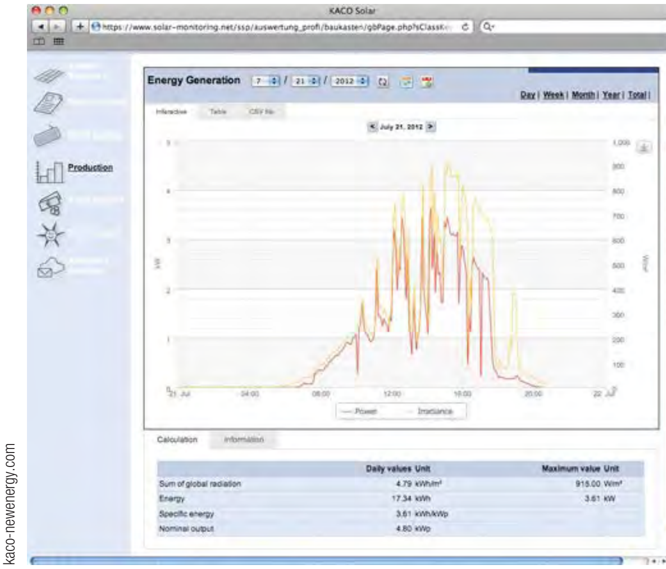
The example's results show three options:

- Three series strings of 8, 9, 10, or 11 modules each (although, at about 4.3 kW of output, an array with 8-module strings is well below the 6 kW inverter rating).
- Four strings of 8, 9, or 10 modules each.
- Five strings of 8 modules each (in some cool climates, this array output, as well as one with four strings of 10 modules each, will exceed the inverter's rating resulting in occasional power clipping).

These tools can be very useful, but care should always be taken to double-check the results by hand-calculations, using the manufacturer's specifications and appropriate parameters, before a final design is reached.



fronius.com



kaco-newenergy.com

Kaco offers online monitoring.

The inverter's *AC output voltage* must match the building or service voltage where it is interconnected. Most U.S. residences are single-phase 120/240 VAC, while commercial buildings may have three-phase service. Many inverters are field-configurable for different output voltages, but, for a few, this must be specified up-front.

Other Options. An inverter may include, or have an option for, integrated disconnects (DC and/or AC), series fusing, data monitoring, remote displays, and a Web interface.

Not all integrated disconnects satisfy *National Electrical Code* requirements for PV array disconnecting (DC) or PV system disconnects (AC). But having a disconnect box that is distinct from the inverter allows the power to be shut off and the inverter removed without exposing energized parts or allowing water infiltration if the inverter needs to be replaced or serviced. If the inverter does not include separable *NEC*-approved disconnects, external ones may need to be installed.

Data monitoring options may be as simple as logging inverter input and output voltage, current, power, and energy; or as complex as reading irradiance levels, array and ambient temperatures, monitoring household usage, and tracking individual module performance. Some inverters offer remote displays, and some offer Web-based monitoring. Being able to check your PV system's performance helps identify problems and minimize lost PV production.

SMA America's Sunny Beam remote monitor.

sma-america.com

Microinverters. Small grid-tied inverters that are paired with each module in the system—aka microinverters—are one of the newest inverter technologies available. Mounted on the rack underneath the module, or integrated into an "AC module," the power conversion takes place right at the PV module so there is no need for high-voltage DC wire runs.

This microinverter from Enphase can send monitoring information to a smartphone.

This SolarBridge microinverter attaches to the back of a PV module.

This Exeltech AC module has a microinverter permanently attached (as shown in the background photo; it is not available as a stand-alone inverter).

An Enecsys microinverter.

Microinverters provide MPPT for individual modules, which not only increases energy harvest but also keeps shading on one module from affecting an entire string of modules. Since there is no high-voltage DC, and the AC output is automatically stopped with removal of grid AC, safety for firefighters is increased. Microinverters track individual module performance, so module-level data monitoring is available, and can help pinpoint modules that are not performing to specifications for warranty replacement.

While microinverters are currently more expensive than string inverters on a purely dollar-per-DC-watt basis, there are other factors to consider. There is slightly more labor involved in mounting a microinverter underneath every PV module (except in the case of AC modules), but there will be less wiring, labor, and wall space needed, since there are no large inverters or DC disconnects to install. On very small PV systems (less than 1.5 kW) it's often more cost-effective to use microinverters—with a string inverter, you'll end up paying for unneeded power capability, since most are not available in smaller sizes. Even though most microinverters carry a 25-year warranty, replacing a failed unit may be difficult and costly, especially on large roof-mounted arrays.

Transformerless Inverters. The *NEC* now allows these, and more manufacturers are making them available in the U.S. market. The main difference between transformer-based and transformerless inverters is that the latter do not use a DC *system* ground, although the system still has full *equipment* grounding (see "Ungrounded PV Systems" in *HP150*). Tranformerless inverters can be more efficient than their transformer-based counterparts (up to about 2% for models available in the United States) and include enhanced ground-fault protection. The inverters weigh less, making installation easier, and they tend to cost less than their transformer-based counterparts.

Efficiency Ratings. Manufacturers have their own efficiency ratings, but for accurate production projections, it's wise to

SMA America's transformerless inverter.

DC Optimizers

DC optimizers track individual module MPPs and condition DC voltage before it's sent to a string inverter. They are small units that mount under modules on the PV rack, much like microinverters. Often, they have a safety feature that allows each unit to cut off DC output power to help ensure firefighters or other emergency responders will not be exposed to high-voltage DC wires between the array and DC disconnect. With the use of DC optimizers, unequal numbers of modules in series strings, shading issues, and different module orientations have less of an impact on PV array power production. DC optimizers offer data monitoring options at the module level and many have Web-based interfaces.

obtain them from an independent source, such as the Go Solar California Initiative (gosolarcalifornia.org). Manufacturers' efficiency ratings (often labeled "Maximum Efficiency" on spec sheets) could be based on testing at lower ambient temperatures and under other conditions that do not reflect realistic field operation, but optimize inverter performance. The Go Solar California Initiative ratings (labeled "CEC Efficiency" on spec sheets) will be slightly lower (generally around 1%).

Choosing an Off-Grid Inverter

An off-grid inverter is sized differently than a grid-tied inverter—the latter has grid power available to supplement PV production. An off-grid inverter must have enough *AC output power* to cover any AC loads that might run simultaneously. For example, if you have 2,850 W of AC loads, then you might choose an inverter with 3,000 W of continuous output power. Any surge requirements (common with compressors and motors, such as in refrigerators, well pumps, etc.) need to be checked against inverter "surge" or "overload" specs (see "Sizing a Battery Based Inverter" in *HP149*).

Since the inverter draws from a battery bank instead of the PV array, the *DC voltage input* needs to match the nominal battery bank voltage (generally 12, 24, or 48 V). Inverter model numbers usually reflect both the AC power output and the DC battery voltage. For example, the OutBack VFX 3648 can produce up to 3,600 AC watts continuously and works on a 48 VDC battery bank.

Schneider Electric's Xantrex XW battery-based inverter.

OutBack Power's off-grid inverter.

Magnum Energy's MagnaSine off-grid inverter.

Apollo Solar's off-grid inverter.

Most quality stand-alone inverters produce a pure sine wave. The AC electricity from the utility is a fairly clean sine wave form, and higher-end inverters match or beat this quality. Modified square-wave inverters tend to be less expensive, but the power quality is not as good. Many appliances actually run fine on a modified square wave, but some loads, including thermostats, clocks, fans, and power tool battery chargers, might not function properly. Sine wave inverters are highly preferred, as they will run motors more efficiently, and consumer electronics with less noise and electrical interference.

AC Output Voltage. Some off-grid inverters have a 120 VAC output, requiring "stacking" two inverters to make 240 V, or need a 120/240 step-up transformer. Other inverters have single-phase 120/240 V AC output. Since most larger generators are also 120/240 V, they should be connected to an inverter that accepts a 240 V AC input, or run through a transformer to step it down to 120 V. Using only one 120 V leg of a 240 V generator can increase generator run time. Three-phase AC loads can also be run with some inverters. Each manufacturer will specify if this is possible and how it is done.

Other Options. Off-grid inverters have many helpful features and programming options. Most have built-in

A pure sine-wave inverter from Samlex America.

Exeltech's XP stand-alone inverter.

Morningstar's SureSine inverter.

Small Stand-Alone Inverters

Boats, small cabins, and portable power stations often have just a few small AC loads. Some may have DC lighting, a fridge, and other appliances, but there are a lot of appliances that won't run on DC.

Some off-grid inverters are made specifically for mobile applications—that is, designed to be less prone to damage from vibration and dirt/dust. They also have an internal transfer switch that removes the AC neutral-to-ground bond when connected to shore power. The smallest of these inverters often don't have much, if anything, to program; they don't usually include AC battery chargers or battery monitors, either.

Choosing the correct size is similar to larger stand-alone inverters: the inverter needs to have enough power to run all of the AC loads, and have the correct DC battery voltage. Most models are 12 or 24 VDC. Since these smaller inverters tend not to be used for motor loads, often they don't have much surge capability.

Models less than about 500 watts tend to have a cigar-lighter plug for the DC connection. Larger units need to be hard-wired into the system. Most have one to two 120 V AC outlets, and built-in fuses to protect the output circuits.

The more economical models may be modified sine-wave, although pure sine-wave models are available. It is important to match inverter power quality with the loads—i.e., don't use a modified sine-wave inverter on sensitive AC loads, like high-quality audio and video electronics. Some inverters have a built-in LVD, but be sure to look at the actual disconnect voltage since often this feature is at a preset (and unchangeable) very low-voltage disconnection (10.5 V is common)—not for protecting the batteries, but to protect the electronics inside the inverter from low input voltage.

A Xantrex monitor.

OutBack Power's MATE3 monitor.

A Magnum Energy monitor.

chargers to charge batteries from an AC power source. They should also have a programmable low-voltage disconnect (LVD) to keep batteries from being overdischarged. Other options may include automatic generator starting, battery monitoring, remote displays, a Web interface, and auxiliary relays (for various functions such as operating a battery box fan).

Grid-Tied with Battery Backup

A grid-tied with battery backup (GTBB) inverter has to work both as a grid-tied inverter and a stand-alone inverter to energize loads when the grid is down. Choosing is fairly simple, since there aren't very many available models (see "Choosing a Battery-Based Inverter" in *HP149*).

GTBB inverters must have a large enough AC power rating to pass through the full PV array output (like a grid-tied inverter) and to power the backed-up AC loads subpanel (like an off-grid inverter). For example, a 4 kW PV array with 2.5 kW of loads on the backed-up subpanel necessitates using a 4 kW inverter to meet the PV array requirement even though the load power needs are less (surge load sizing applies, as well). The battery bank voltage must match the inverter, as in off-grid systems, and the AC output voltage must also match the utility voltage, as in grid-tied systems.

Many features and options of GTBB inverters are the same as for off-grid inverters—some GTBB inverters can be used as off-grid inverters. There will simply be some programming differences to let the inverter know whether it needs to interconnect with the grid.

Access

Lena Wilensky (nunatakenergy@gmail.com) is co-owner of a small RE design and install business, Nunatak Alternative Energy Solutions, in Crested Butte, Colorado. She is a NABCEP-certified PV installer, IREC-certified affiliated master trainer, contract instructor for Solar Energy International, and mother.

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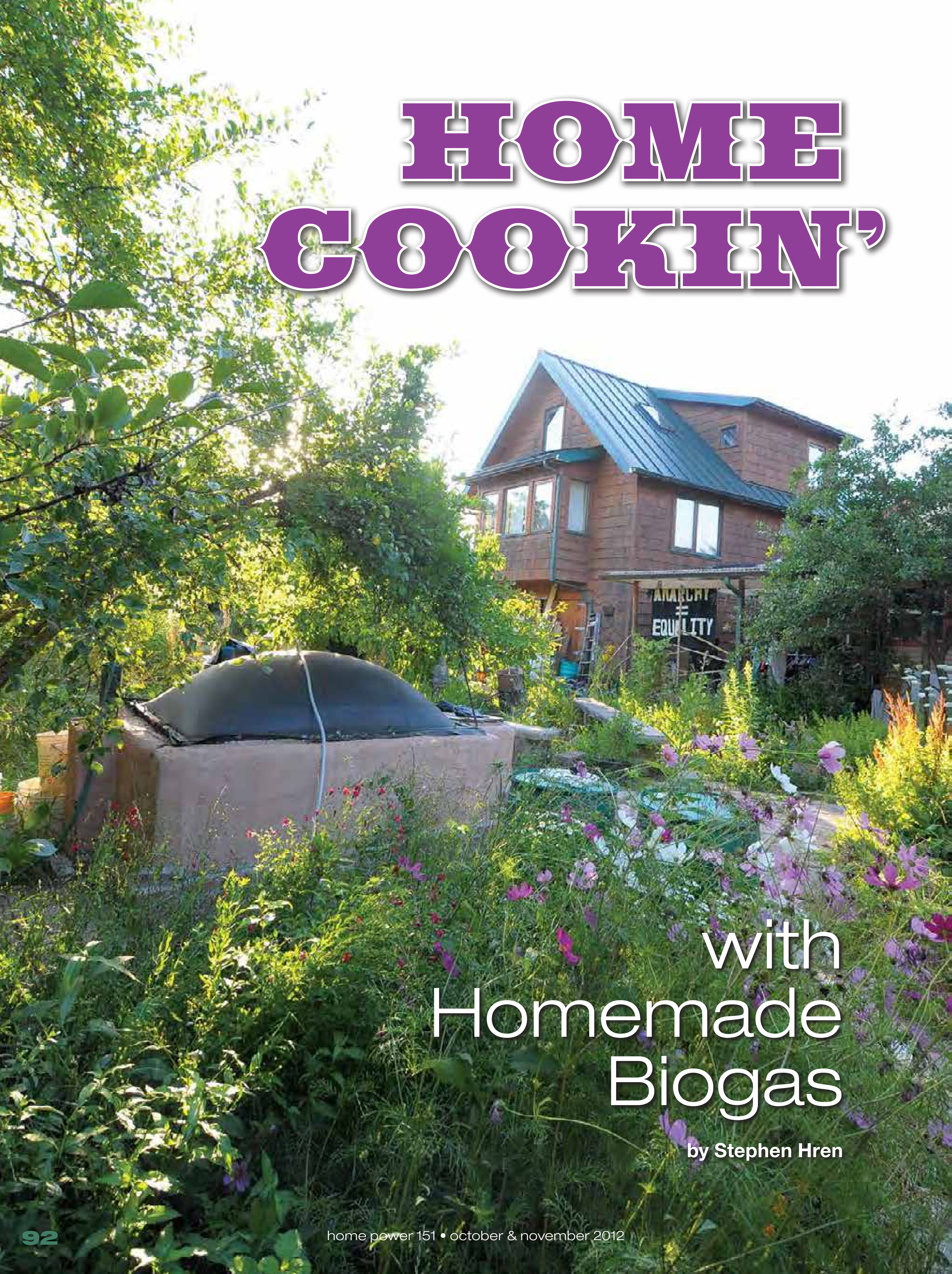


with Homemade Biogas

by Stephen Hren

Methane is composed of carbon and hydrogen—CH_4. It has an octane rating of 110 and produces about 1,000 Btu of heat per cubic foot of gas.

Biodigester Efficiency & the Environment

Cooking fuel is greatly needed in less industrialized nations, especially in rural areas. Several countries, such as India and Costa Rica, provide crucial government support for biodigester technology, but none more so than China. More than 30 million biodigesters have been built there, supplying renewable cooking and lighting gas for more than 100 million people.

Anaerobic composting and its biogas production have major advantages compared to traditional aerobic composting and burning biomass for cooking and lighting. These advantages are opening the door to a more sustainable rural economy in China, especially in Sichuan province, where the modern biogas movement began and government support and technical know-how is strongest.

Probably the greatest advantage with biodigesters is in their efficiency—biogas often achieves efficiencies of 60%, compared with about 10% for the typical homemade biomass-burning cook stove. Using less biomass means more living trees, less air pollution and greenhouse gas emissions, and a vast improvement in household air quality. Local water quality and sanitation is also greatly improved, as human and animal wastes can be composted in a sanitary manner. And lastly, the end product is a quality fertilizer, rich in nitrogen and free of pathogens. While there is much in China to bemoan on the environmental front, the more than 4 million biodigesters being built in rural China each year certainly provide one of the bright spots in a nation lurching toward industrialization.

About five years ago, writer and renewable energy aficionado Warren Weismann was researching ancient Greece for his novel when he stumbled across information that the Greeks had built anaerobic digesters to produce methane. He then read about similar archaeological evidence in ancient Syria and China. But it was the modern biogas boom in China that got him most excited and distracted him from his writing career: Tens of millions of home-scale biodigesters have been built in China over the last century, with the pace of construction still accelerating. Warren wanted one for himself.

The Maitreya Ecovillage biodigester turns 15 pounds of kitchen scraps and garden clippings into a day's worth of cooking fuel for the community's kitchen.

Isaac Marquez (3)

After a few years of further research, including conversations with colleagues in India and Nepal, where small-scale biogas production is prevalent, Warren modified traditional designs to create a plan for his own 700-gallon biodigester. He was living at Maitreya Ecovillage, a three-block community and green-building-oriented neighborhood near downtown Eugene, Oregon. After building his first biodigester last year, he's become increasingly excited about the possibilities for home-scale biogas, and has established Hestia Home Biogas to build biodigesters locally and consult on biodigesters across the globe.

Maitreya resident Christa Stark loads kitchen scraps into the digester.

Inside a Biodigester

A biodigester is a sophisticated way to harvest fuel from the complex carbon chains of organic matter—energy collected by plants from the sun as they grow—without combusting them directly. Direct combustion of carbon causes air pollution, a loss of much of the nutrient value of the biomass, and a poor energy harvest—especially when used for cooking or lighting, as most of it goes up in smoke. Burning wood, even in an EPA-certified woodstove, can produce more than 500 times the fine particle emissions of burning natural gas.

As new plant material is fed into the digester, it is first attacked by acidogenic bacteria, which break the chains holding together some of the more complex plant matter, especially cellulose—the structural backbone of most plants. Ammonia

Stirring the scraps into the muck exposes them to active methanogenic bacteria.

Isaac Marquez (3)

Back from Obscurity

Biogas has been used for lighting for at least a century, and possibly millennia. But it was mostly abandoned in the United States after cheap and abundant fossil fuel was harnessed in the early 20th century. Home-scale biodigesters have remained on the sidelines in the developed world, but are poised for a comeback as interest in a replacement fuel increases.

There are good reasons to consider building biodigesters for a community, small farm, or even home. Biodigesters yield two products that are extremely useful for the home and garden—high-nitrogen compost and flammable gas.

Biodigesters anaerobically (without air) break down organic matter in a slurry held in a tank. The nitrogen remains in the composted slurry as ammonia, a vital plant nutrient. The flammable gas produced by biodigesters is about two-thirds methane and one-third carbon dioxide—very similar to natural gas—making it a good cooking fuel. Cooking requires intense direct application of heat on demand, and renewable options for accomplishing this are limited. Solar energy is dispersed and not consistently available, making solar cooking challenging, and burning wood contributes to particulate pollution and further depletes diminishing resources in the developing world. Cooking is not a huge consumer of energy in the industrialized world, but doing it more sustainably is challenging. Unlike cooking with solar electricity, biodigesters can be assembled with readily available materials by a handy homeowner. Any type of propane or natural gas stove will run on biogas. For maximum efficiency, propane stoves will require a larger air inlet.

Cleaning up and adding water to replace what is drawn off as liquid compost.

and acetates (mostly acid) are produced, lowering the pH and using up any oxygen in the process. Acetates are the perfect food for methanogenic bacteria, as long as the slurry they reside in is not too acidic and all oxygen has been removed. They consume the acetates and produce methane (CH_4) and carbon dioxide (CO_2), along with a lesser amount of other gases and residues depending on the original feedstock.

In consuming these acids, the methanogenic bacteria raise the pH and keep it hospitable for both the acid-formers and themselves, both of which would perish if the pH dropped too low. The high-nitrogen ammonia (a byproduct of the breakdown of plant proteins) remains dissolved in the slurry, unlike in aerobic composting where it is released as a gas. Although both the acid-formers and the methanogens can suffer from rapid changes in living conditions created by the addition of feedstock, the methanogens are especially vulnerable to low pH and the introduction of too much oxygen. For this reason, biodigesters generally work on the principle of steady applications of new feedstock in regular intervals, rather than adding large amounts of biomass at once.

As the biomass decomposes, methane and carbon dioxide are created, inflating the rubber bladder to create pressure.

Isaac Marquez (2)

Tank Troubleshooting

Too acidic. Generally if there's a problem, it's that the slurry is too acidic (pH below 7). If there is a lot of new, raw, green material placed in the digester or if too much material is added at once, the acid-forming bacteria have a field day. The methane bacteria are so annoyed by the high acid concentration, they simply can't function. When this occurs, it can take a long time for the methane process to get underway naturally. Low pH is a constant risk and must be countered by plenty of carbon waste, such as leaves and straw, or wood ashes.

If a measured amount of new material—no more than one-fortieth of the total liquid volume of the tank—is added, then the new material has to be dilute enough not to upset the balance. At startup, though, there's a lack of microorganisms and an inclination toward excessive acidity. Understanding this, we can see why some of the early literature on making methane states that the startup time can be anywhere from three weeks to three months.

I mentioned the acidity problem to a friend with whom I was working at the time. He said, "I make a lot of wine at home. Every once in awhile, I have the same problem. When I do, I add a little baking soda. It straightens out the condition right away."

The baking soda added to my digester worked like a charm. Within three days, I had methane on the way. This is the secret for keeping your digester sweet and happy. Just add a little at a time until the pH is just right. If the pH keeps dropping, add baking soda periodically until the acid-forming bacteria are no longer producing excessive acid. Don't be fooled if a lot of gas is produced. The baking soda itself will produce some carbon dioxide.

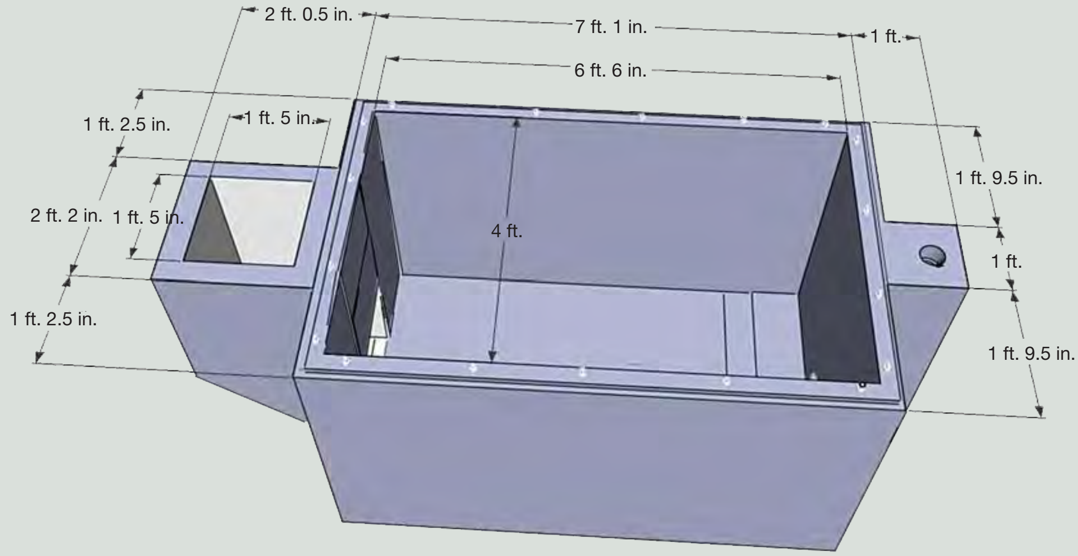
If the pH gets so low the digester "sours," it is very difficult to revive and must be pumped out by a septic service and restarted. The Maitreya digester has not experienced this problem.

Too cold. You'll need to know how hot the tank is, day to day, season to season. To eliminate the guesswork, install sensors both inside and outside the tank. Record these temperatures over a period of time. Then you will know how efficiently the tank is retaining heat, at what rate the temperature drops when no heat is added, and how much energy is needed to raise the temperature. If this is done, then a reliable calculation can be made of how much heat is needed to maintain working temperature if "free" heat is not available. Heat conservation, more than any other factor, determines whether a methane system will "fly" or not.

—Adapted from "The Methane Process"
by Al Rutan (*HP28*)

There are several different types of methanogenic bacteria that will colonize a digester, depending upon the slurry's temperature range. The two ranges of interest to home-scale biodigesters are the cryophilic (50°F to 80°F) and the mesophilic (95°F to 125°F). There is a dead zone between these two temperature ranges that must be avoided. Warren's biodigester operates in the cryophilic range. While mesophilic methanogens can break down material several times as quickly as their cryophilic counterparts, consistently maintaining high temperatures consumes a great deal of energy—which can make a net energy loss for smaller biodigesters.

Building the Biodigester



Hestia biodigesters are approximately 5 by 7 feet wide by 5 feet deep, providing about 700 gallons of capacity. Slurry occupies about 600 gallons of this biodigester; the remaining space is for the gas that's produced. The design is straightforward: an insulated concrete vessel is topped with a steel frame that holds an EDPM pond liner, which expands as gas is produced. There's an inlet for adding feedstock and an outlet for removing composted slurry. A closed loop of PEX tubing in the bottom of the tank is plumbed to an on-demand water heater to add heat when the slurry temperature drops below 50°F—the temperature at which cryophilic methanogenic bacteria go dormant and stop producing gas. If the climate is mild, it may be enough to build a hoop house over the tank to keep the slurry sufficiently warm in winter. Alternatively, the biodigester could be allowed to go dormant during the colder months.

The first step in building the Hestia's biodigester is to excavate 28 inches below grade, which makes the height of the inlet right for easy addition of feedstock by 5-gallon bucket. Warren likes to make sure the digester is visible from the kitchen, since the inflation of the rubber top indicates if there is sufficient gas available for cooking Alternatively, a simple pressure gauge could be added to the gas line in the kitchen.

After excavation comes building the wall forms for the 2 cubic yards of aggregate-free concrete, which must be poured all at once to avoid leaks through the walls. A 4-inch PVC outlet pipe and any PEX tubing for adding hydronic heat must be set in place. The PEX tubing will rest on the bottom of the floor of the tank, so two short pieces, one for entry and one for exit, must be embedded in the wall so the rest of the radiant heating system can be attached later.

A concrete truck with a pump is best to fill the forms in one pour. A concrete vibrator (also called a "stinger") will help remove air bubbles' weak spots from the concrete. The massive weight of the wet concrete and the agitation of the stinger make it important to solidly secure the forms.

After the concrete cures and the forms are removed, three coats of "moose-milk" finish—a mix of Portland cement and acrylic latex—

Left: The outer forms are reinforced to withstand the pressures of the poured concrete.

Right: The interior forms, with floor and wall reinforcements visible.

Warren Weismann (3)

Warren Weismann (3)

The finished concrete pour, with rubber bladder in place.

Details of the frame, gasket, and rubber bladder assembly.

Rigid foam board is used to insulate the tank and help maintain the correct temperature for the bacteria.

is painted on to help prevent leaks. The first is a bonding coat of watery-thin consistency. The second coat is thicker (like peanut butter), with a higher ratio of Portland cement. The finish coat is another thin application. After sealing, the tank is filled with water for a leak test. If this goes well, the outside of the tank can be insulated with 3 inches of rigid foam board insulation and then backfilled. For aesthetics, Warren wraps the exterior of the biodigester in chicken wire and then stuccos it.

The 40-mil pond liner and steel frame that serve as the tank top are held in place with 18 anchor bolts inserted into the top of the concrete tank at the time of the pour. The steel frame can be fabricated or purchased from Hestia.

The gas line is attached to a regular barbed fitting secured with a hose clamp. The rubber membrane is sandwiched between two washers and nuts on the threaded end of the fitting. The gas line is a 1/2-inch flex hose, which is transitioned to a standard PVC gas pipe when it goes underground. Burying the PVC line protects it from photodegradation and developing cracks that could lead to gas leaks.

The most common problem is water buildup in the gas line, which can interfere with gas flow. When this occurs, the gas line must be picked up and the water drained back into the digester. Ideally, a water separator could be combined with a pressure-relief valve on the bottom to eliminate excess moisture when the valve is tripped.

Tank Alternatives

Besides building your own biodigester tank, repurposing old food storage or other tanks is a possibility for biogas generation. You'll just need to size it correctly and make sure it's leakproof. A general rule is that the tank needs to be 50 times the size of the daily input to allow for some space for gas to collect. If your input is 15 gallons of material per day, you'd need a 750-gallon tank.

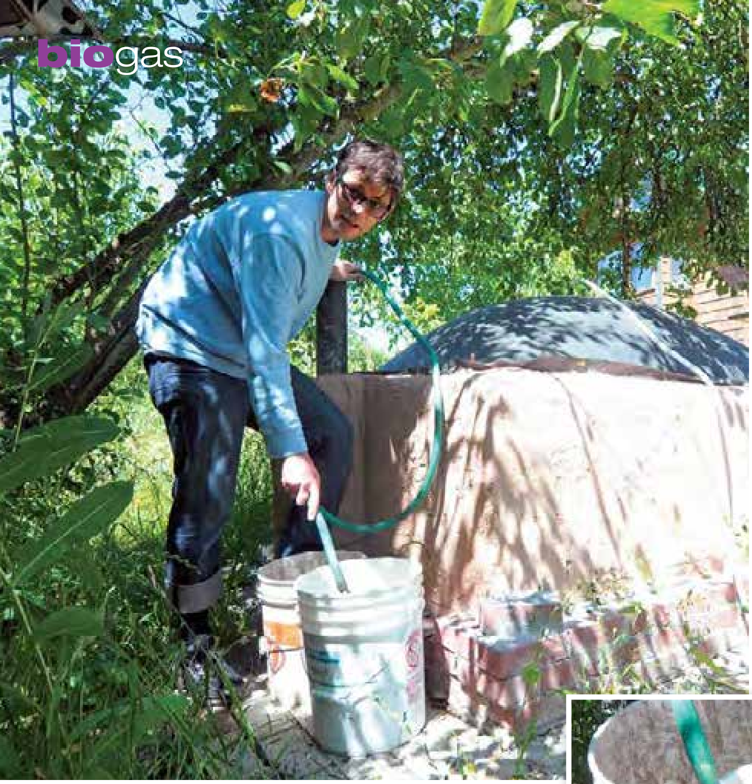
Construction Time & Costs

For this particular biodigester, construction time will vary depending on a person's construction experience or if a professional concrete contractor is hired to pour the digester tank. Time will vary from several weekends to several days, separated by a seven-day concrete-curing period.

Materials will cost $1,000 to $1,200, depending on the price of ready-mix concrete in your area and if the concrete company will charge you a "short-load" fee for ordering only 2 yards of concrete. The project can be broken down into excavation and concrete; plumbing and gas piping; and external masonry. The concrete, rebar, battens, and anchor bolts run about $500. Warren highly recommends spending the extra $200 to $300 for a concrete pumper truck to avoid having to "bucket brigade" the concrete. The plumbing and gas piping will be an additional $200, and external insulation and masonry, another $300. (To purchase a complete plan set for $89, visit hestiahomebiogas.com.)

Flexible gas lines run from the top of the bladder to a valve and buried rigid plumbing. A stucco and brick facade helps the digester integrate with the garden landscape.

Isaac Marquez



The scraps are shoved into the digester with a pole, and this slight agitation helps mix the slurry, exposing the material to the bacteria so it can be thoroughly composted. The tank can also be topped off with water at this time if the slurry level is low. As new feedstock is added, it displaces an equal volume of composted slurry through the outlet, which is captured in a 5-gallon bucket and then added to nearby gardens. Biodigesters prefer a carbon-to-nitrogen ratio similar to a conventional aerobic compost pile, with about 25:1 being ideal. Too much carbon-rich material (grass clippings, newspaper, etc.) will slow the digester. Manure is the most common nitrogenous material to add to rebalance a slow digester.

The biodigester at Maitreya has been operating for more than a year with consistent results. Warren and Hestia Biogas are in the final stages of getting city permits for new biodigesters, to bring an official stamp of approval to a renewable energy technology with great promise for any homestead.

At the output, the nitrogen-rich liquid fertilizer is extracted from the digester, which produces 5 to 10 gallons per day.

The liquid fertilizer can be added directly to plants or covered with dirt or mulch to keep beneficial ammonia in the soil.

Isaac Marquez (3)

The released CO_2 and CH_4 gases percolate through the slurry to the top of the tank. Once enough biogas accumulates, the pressure created inside the expanding rubber top reaches 0.25 to 0.5 psi, enough to move the gas through the delivery pipes and use it for cooking or lighting. As new material is added to the tank through the inlet, it displaces an equal amount of slurry through the outlet, which can be applied directly to the garden. Once applied, covering the slurry with soil helps keep the ammonia from turning to gas and losing its coveted nitrogen.

Operating the Digester

Warren's biodigester at Maitreya primarily uses kitchen waste once in operation. Getting it up and running, however, requires a whole mess of ruminant manure—about 300 pounds' worth. There happened to be an alpaca farm nearby, and so he used alpaca manure, but any ruminant manure will be loaded with plenty of methanogenic bacteria. He also added a few gallons of kitchen compost and tree leaves, and then filled the tank to 600 gallons.

It takes a minimum of two to three days before a biodigester begins to produce gas, since the acid-forming bacteria need to do their work before the methane-producing bacteria can go to work. About 10 to 15 pounds of kitchen scraps are collected and added to the biodigester daily, producing an average of about 70 cubic feet of biogas, which is the only source of cooking fuel for the community's kitchen. When the methane content begins to get low, the flame will begin to burn orange. This is remedied by feeding the digester.

Biodigester Maintenance, Costs & Risks

Biodigesters are living things, and just like a vegetable garden or flock of chickens, they require regular maintenance to function properly. It's important to avoid adding materials that can overwhelm or clog up the digester, including wood or plant stalks thicker than your finger; large amounts of meat; bones (unless they are ground up); fresh citrus or apples; and fresh chicken manure (which is OK only if it's allowed to dry first). A few 5-gallon buckets of digested slurry will need to be removed every few days for a 700-gallon digester like the one at Maitreya, but otherwise the digester shouldn't ever need to be cleaned out.

Regular use of the gas is important to avoid explosion hazards. Letting the digester sit for more than a week can create an abundance of biogas. Operating the digester at its natural pressure, without further gas pumps to pressurize it, in addition to the appropriate check- and pressure-relief valves, helps ensure that an unsafe buildup of gas doesn't occur.

A biodigester of this size should be cleared with your local fire marshal, who may or may not be sympathetic to its construction. Biodigesters are not common in North America, and some education of officials will likely be required. Warren has been working with the City of Eugene for formal approval, and the case is pending.

Isaac Marquez

Now we're cooking with (bio)gas.

Access

Author and builder Stephen Hren (stephenhren@gmail.com) lives in Durham, North Carolina. His latest book is *Tales from the Sustainable Underground: A Wild Journey with People Who Care More About the Planet Than the Law.*

Hestia Home Biogas • hestiahomebiogas.com

Biodigesters in China • bit.ly/ChinaBiogas

Methane: Planning a Digester by Peter-John Meynell

Plug-In Vehicles

Ready for Prime Time?

Banish the notion of a souped-up golf cart—plug-in electric vehicles are being manufactured that replace the traditional internal combustion engine (ICE) automobile. If you're looking for an EV, here are answers to the questions you might ask before you buy.

by Andy Kerr

What are the various kinds of electric vehicles?

All commercially manufactured electricity-powered vehicles have an electric motor drive, automatic start/shutoff, and regenerative braking (an energy recovery mechanism that slows a vehicle or object down by converting its kinetic energy into electrical energy, which helps charge the propulsion battery). There are three varieties of electric vehicles.

Hybrid electric vehicles (HEVs) are powered by an ICE, as well as by electrical energy stored in a battery. The battery is charged through the ICE and regenerative braking. Typically, HEVs are not plugged in to charge (see PHEVs, below). The Toyota Prius is the most common HEV.

Electric vehicles (EVs) are powered only by the battery, which is recharged by plugging the vehicle into an electric power source (and to a small degree, by regenerative braking). Examples are the Nissan Leaf and Ford Focus Electric.

Plug-in hybrid electric vehicles (PHEVs) are powered, like an HEV, through a combination of an ICE and an electric motor. Unlike an HEV, a PHEV can be plugged into an electric power source to recharge the battery, in addition to recharging it using regenerative braking. There are two types of PHEVs:

- Extended-range PHEVs, such as the Chevrolet Volt, which has a gasoline engine that spins the electric motor (which propels the vehicle) when the battery reaches a low state of charge.
- "Blended" PHEVs, such as the Toyota Prius Plug-in, where the electric motor or gasoline engine can work singly or jointly to power the engine.

This article focuses mainly on EV and PHEVs, as they are the only vehicles that can accept an outside electrical charging source.

Pros & Cons of EV Ownership

	Pros	Cons
Less expensive fuel	✓	
No tailpipe emissions (with pure EVs)	✓	
Quieter	✓	
Fun to drive	✓	
Coolness factor (the "Prius effect")	✓	
You may save money (depending on fuel prices & how much you drive)	✓	
Limited range (EVs only)		✓
Higher initial cost		✓
Limited selection		✓

The all-electric Nissan Leaf is one of the few EVs on the market.

Courtesy Nissan Motor Co.

What EVs are or will soon be available?

Several models are on sale now and more are coming. Plugincars.com maintains up-to-date information on current and prospective EVs. Many new models show a "2012" availability date, which refers not to the model year, but the manufacturers' best hopes for getting it to market. Plugincars.com currently features 31 vehicles, 12 of which are available now; five more are expected before the end of 2012.

The Chevrolet Volt is a plug-in EV paired with a gasoline engine for extended range.

Courtesy General Motors

What about "range anxiety?"

According to *Consumer Reports*, 77% of EV drivers suffer from "range anxiety"—the dread of running out of energy before your trip is completed and being stranded. But in reality, 78% of Americans who commute by car drive 40 miles or fewer daily. Most people buy an automobile to meet much more than their average, typical, or normal need. They buy a car based on taking a few long trips each year rather than for everyday use. According to the Federal Highway Administration, the vast majority of automobile trips are one to 10 miles, well within the range of any EV. Only 1% of vehicle trips are in excess of 100 miles.

- The Chevrolet Volt addresses range anxiety by running exclusively on electricity for the first 35 miles. With its 9.3-gallon fuel tank, it can travel another 300 miles or so using its gas engine.
- The Toyota Prius Plug-in travels 11 miles on a fully charged battery, and then can go another 500 miles or so using a combination of its gas engine and electric motor, for a combined 49 mpg. A smaller battery means a more limited all-electric range, but it also means a lower purchase price.
- The Nissan Leaf and Ford Focus Electric are both all-electric and have a maximum range of about 75 miles.

For those relatively few times your EV won't go the distance, you can rent an ICE car or use a car-sharing service such as Zipcar or Car2go (see Carsharing.net).

How do I charge an EV?

Like any other battery-powered device, an EV's battery will need to be recharged regularly—depending upon how much the EV is used. The table below shows the EV charging options available now—and those coming in the future.

For levels 1 and 2, the Society of Automotive Engineers J1772 standard connector is the norm. Level 3 and DC fast-charging connector protocols have yet to be standardized. Inductive (wireless) charging, where a vehicle need only be placed near the charging unit for the batteries to be recharged, is also under development.

Courtesy Toyota Motor Corp.

Toyota's Prius Plug-in uses the J1772 standard for its charging connectors.

The J1772 standard specifies a five-pin connector for delivering 120 or 240 VAC to an EV. Pins include AC Line 1 and Line 2, ground, controller pilot, and a proximity detector.

Courtesy Society of Automotive Engineers

EV Charging Equipment Options

Charging Option	Primary Use	Current Supplied to Vehicle	Charging Current (Amps)	Charger Input (Volts)	Power (kW)	Hrs. to Recharge*
Level 1	Residential	AC	≤15	120	≤1.8	6–20
Level 2	Residential	AC	≤30	240	≤7.2	3–8
	Public	AC	80	240	≤19.2	3–8
Level 3	Public	AC	To be determined			≤0.5
DC Fast Charging	Public	DC	200	480	50–150	≤0.5

*Varies, depending of battery state of charge; Source: DOE Energy Efficiency and Renewable Energy Vehicle Technologies Program

How does maintenance compare between plug-in and conventional ICE vehicles?

With an EV, there is no regular scheduled maintenance needed for the battery, electric motor, and associated electronics. Fewer moving parts means less maintenance and replacement. Only after many charge/discharge cycles will the propulsion battery need to be replaced. But even the batteries in the earliest Prius models regularly go beyond the warranty period, achieving 100,000, sometimes 150,000, and occasionally even 200,000 miles, with little significant deterioration.

Regenerative braking not only recovers energy that would be lost in braking, but reduces brake wear. With HEV and PHEVs, the ICE isn't running all the time, meaning longer intervals between oil changes and other engine maintenance.

Are electric vehicles as safe as petroleum-powered vehicles?

It was widely reported in the media that, three weeks after a side-impact test conducted by the National Highway Traffic Safety Administration, a Chevrolet Volt's crystallized battery coolant ignited from current in the battery. As a result, General Motors has upgraded the steel structure and cooling system surrounding the battery.

But there have been no real-world battery-related Volt fires. NHTSA closed its investigation saying, "Based on the available data, NHTSA does not believe that Chevy Volts or other electric vehicles pose a greater risk of fire than gasoline-powered vehicles." Crash safety information for all vehicles can be obtained from the Insurance Institute for Highway Safety (iihs.org/ratings) and the NHTSA (safercar.gov).

As plug-in vehicles are quiet, they can be a danger to hearing- and/or sight-impaired pedestrians. A new government standard is intended to be in place by the summer of 2012 that requires an alert mechanism.

Q Does driving an EV cause less pollution than driving a petroleum-powered vehicle?

Yes, an EV pollutes less—even if you're recharging with electricity from a utility that offers the dirtiest portfolio of mostly coal- and oil-fired electricity generation. Of course, you can reduce your EV pollution if more of your energy comes from CO_2-free wind, solar, hydro, and/or nuclear sources. Plugging various ZIP codes into the U.S. EPA's power profiler, we find that California's electricity mix includes the least coal (1%) and the most nonhydro renewable energy (10%). In contrast, West Virginia generates most of it electricity with coal (69%), with negligible contributions from renewable sources (see 1.usa.gov/EPAPowerProfiler).

Using the national average of about 70% fossil-fuel-based electricity in a state's energy mix, a PHEV has slightly more greenhouse gas emissions than an HEV. In states less reliant on fossil fuels for electricity, PHEVs pollute less than HEVs. In states more reliant on fossil fuel, PHEVs pollute far more than HEVs (see table below).

Because they are much more efficient users of energy—no matter the electricity source—EVs and PHEVs always have fewer greenhouse gas emissions compared to conventional gasoline vehicles. You can learn about your state's carbon emissions at the Department of Energy's Emissions from Hybrid and Plug-In Electric Vehicles website (http://bit.ly/AFAVDCemissions).

The Union of Concerned Scientists report, *State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings Across the United States*, found that EVs fueled from the dirtiest of utilities emit less CO_2 than a new ICE compact car that averages 27 mpg. If powered by the cleanest grid, EVs beat the best HEV. If powered by wind- or solar-generated electricity, an EV will have no CO_2 emissions.

Typical Carbon Emissions Per Vehicle (Lbs. of CO_2 Per Yr.)

	EV	PHEV	HEV	ICE
National average	8,035	8,875	8,571	13,043
California	4,329	6,123	8,571	13,043
West Virginia	9,870	10,324	8,571	13,043

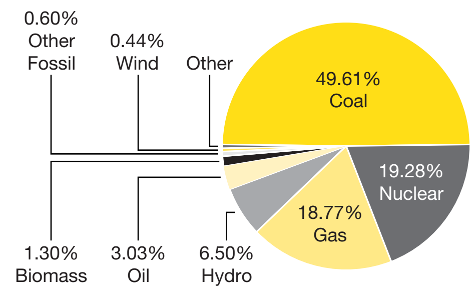
Source: U.S. DOE Alternative Fuels & Advanced Vehicles Data Center

Courtesy Ford Motor Co.

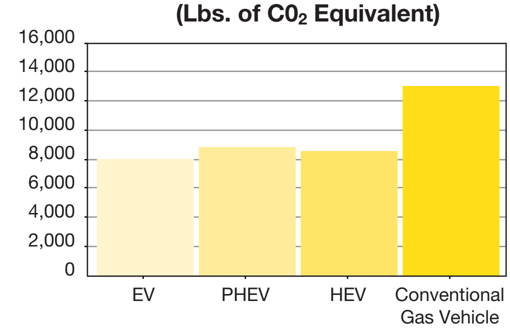
Ford's Focus Electric has a maximum range of 76 miles before its batteries need to be recharged.

Electricity Sources & Vehicle Emissions

Electricity Sources



Annual Emissions per Vehicle (Lbs. of CO_2 Equivalent)



Source: DOE Alternative Fuels & Advanced Vehicles Data Center

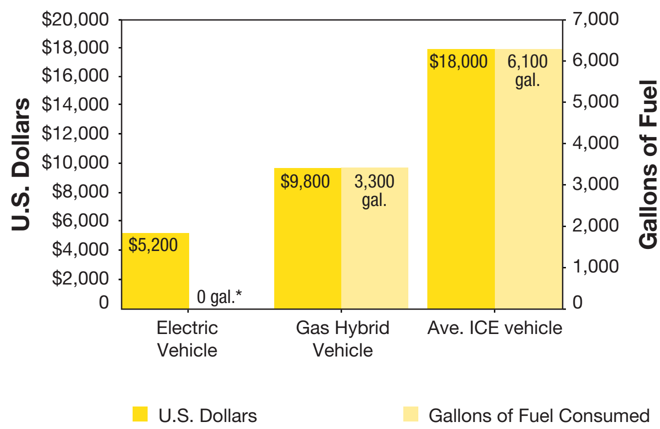
Will saved operating costs offset an EV's higher purchase price?

This depends partly on how much you drive—the more you drive, the more you will save. It also depends on the initial purchase price of the EV or PHEV compared to an ICE vehicle. In general, the higher the upfront capital cost of a plug-in car, the lower the per-mile operating cost.

Cost recovery depends upon how much you paid for the vehicle's "EV-ness." To determine that, you must compare what you will pay for a PHEV or EV to the most similar ICE model. For example:

- The Chevrolet Volt ($32,780 MSRP, after $7,500 federal income tax credit) costs $9,590 more than its closest ICE equivalent, the well-accessorized Chevrolet Cruze Eco.
- The Toyota Prius Plug-in (starting at $25,000 MSRP, after the credit) costs $2,945 more than a Toyota Camry.
- The Nissan Leaf (starting at $27,700 MSRP, after credit) costs $16,710 more than a Nissan Versa sedan.
- The Ford Focus Electric ($31,500 MSRP, after credit) costs $13,200 more than an ICE Ford Focus.

Lifetime Fuel Cost & Consumption



*In this comparison, the EV consumes approximately 57,000 kWh (an equivalent of 99 mpg) in its lifetime.
Note: Fueling/charging costs are based on gasoline costs of $3.50/gallon; an electricity price of $0.11/kWh; a discount rate of 3%; 166,000 lifetime miles; and an EV efficiency rating of 0.34 kWh/mile.
Source: *State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings Across the United States* (www.ucsusa.org/EVfacts).

The generally useful Department of Energy's vehicle cost calculator (bit.ly/AFDCcalc) uses the miles you drive and the cost of gasoline. But it bases its calculations on the regional average price of electricity, assumes maintenance costs per mile are the same for both EVs and ICE vehicles, and presumes a five-year car loan at 10% interest. If the calculator allowed users to change these parameters, it would be provide a more accurate result.

What government and other incentives are available?

EVs and PHEVs qualify for up to $7,500 in federal income tax credits. Many states offer other incentives as well. For example, Californians can get a $2,500 rebate on qualifying vehicles; Oregonians can take an income tax credit equal to 25% of the cost of an at-home charging station ($750 maximum) or 35% of the cost of a business charging station. District of Columbia residents receive reduced registration fees for the first two years of the car's ownership; plus, the sales tax is waived on the vehicle purchase. You may also be able to get time-of-use (TOU) utility pricing so you can coordinate recharging your vehicle when electricity demand (and rates) are low.

There are also private and utility incentives, including free at-home charging stations. The DOE's Federal and State Incentives and Law website (bit.ly/AFDCincentive) can help you determine your eligibility. For example, in portions of California, you can take a state tax credit after installing a charging station at your home. San Diego Gas & Electric offers customers lower rates for EV charging.

The Toyota Prius Plug-in costs about $3,000 more than a comparable Camry, and about $8,000 more than the Prius without plug-in capability.

Courtesy Toyota Motor Corp.

Q How do fuel costs compare?

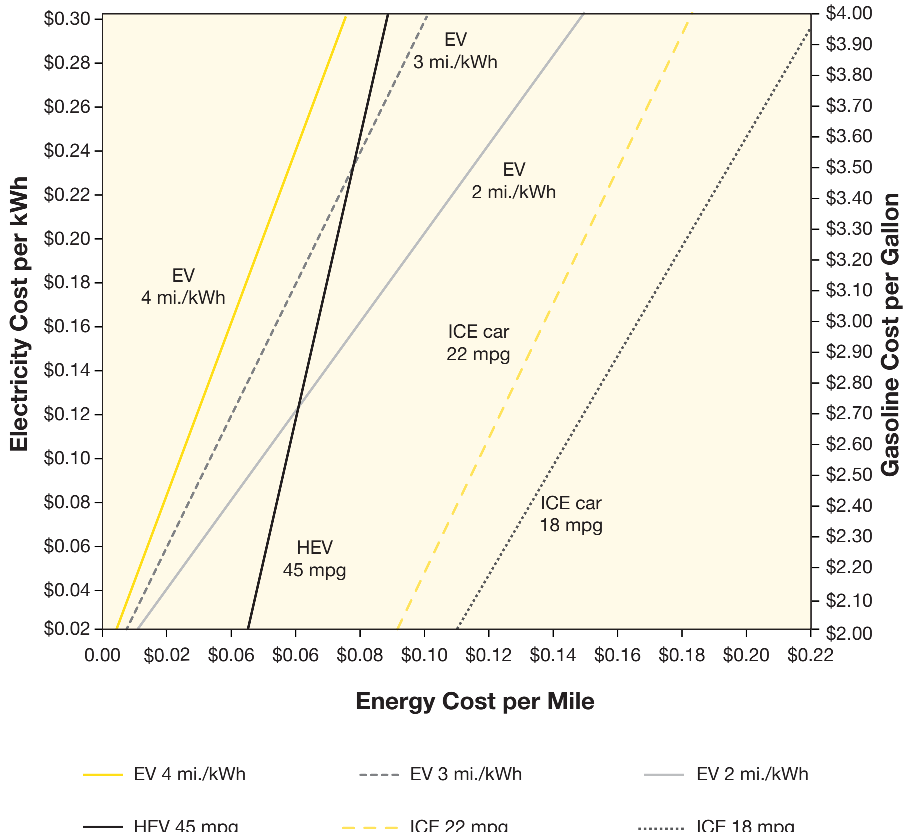
The DOE estimates that conventional ICE vehicles cost 10 to 15 cents per mile in fuel (gasoline or diesel). EV's typically cost 2 to 4 cents per mile for fuel (electricity). A PHEV's fuel costs usually fall somewhere between the two, depending on how much the gasoline engine is used to supplement the electric motor.

In June 2012, the national average price of regular gasoline was $3.60 per gallon. Gasoline prices are generally expected to rise as demand increases in the developing world and supplies tighten due to availability.

In 2010, the average residential cost of electricity was 11.6 cents per kWh. It varies quite a bit by state and between locales (compare Wyoming's average of 6.2 cents to Hawaii's average of 25.1 cents), depending upon the utility.

The graph (upper right) can help you compare costs for an EV that gets 2, 3, or 4 miles per kWh versus an ICE vehicle that gets 18, 22, or 45 miles per gallon (the latter is an HEV). Whether EV or ICE, a vehicle's operating cost has two variables: the fuel cost (cents per kWh or dollars per gallon), and the vehicle's efficiency (miles per kWh or miles per gallon). You can determine the energy cost per mile for either kind of fuel if you know the fuel cost. How much less an EV will cost to operate compared to a gasoline vehicle depends on the vehicle's efficiency and your fuel costs.

Energy Costs



US DOE

The EPA's new-car label for EVs includes both fuel and environmental information for easier comparisons.

Grocery-Getters

Neighborhood electric vehicles (NEVs) are street-legal but limited to low-speed roads. With a maximum loaded weight of 1,850 pounds and a top speed of 25 mph, these vehicles have their place—but not on the open road. Best known is the Polaris GEM e2.

Q: Any last thoughts?

Do your homework before you buy: Regardless of the propulsion technology, a car is a car is a car. Is it reliable? Does it have enough cup holders to satisfy you? Check out traditional sources of new car information and evaluation such as Consumer Reports, *Car and Driver* magazine, and Edmunds.

An electric car is not (yet) for everyone. But as gasoline prices continue to rise, EVs and PHEVs are bound to become a more attractive and affordable option.

Access

Andy Kerr (andykerr@andykerr.net) writes about renewable energy and energy efficiency from the dual perspectives of a net-zero energy homeowner in Ashland, Oregon, and is a policy wonk and advocate in Washington, D.C.

Other Resources:

Consumer Reports • consumerreports.com

Car and Driver magazine • caranddriver.com

Edmunds • edmunds.com

Electricity Doesn't Come in Gallons

To help consumers compare the fuel economy of an EV or PHEV, the EPA requires window stickers for gasoline, electric, and plug-in hybrid vehicles. For PHEVs and EVs, you'll find "miles per gallon equivalent" (mpg-e). A gallon of gasoline has the energy equivalent of 33.7 kWh of electricity—so a car consuming 33.7 kWh per 100 miles will be rated at 100 mpg-e.

MPG-E is only useful when comparing electric vehicles or PHEVs in electric mode. The new EPA PHEV label shows a gasoline-only mpg rating. The actual mpg-e for PHEVs will vary with the miles driven on electricity versus gasoline. You'll also find a one-to-10 fuel economy and greenhouse gas (GHG) rating and similar smog emissions (tailpipe only) rating on the label.

EPA One-to-10 Ratings

Rating	MPG	CO_2 Emissions Per Mile (Grams)
10	38+	0–236
9	31–37	237–290
8	27–30	291–334
7	23–26	335–394
6	22	395–412
5	19–21	413–479
4	17–18	480–538
3	15–16	539–612
2	13–14	613–710
1	0–12	711+

Source: Environmental Protection Agency

Load-Side Connections: Article 705

by Brian Mehalic

The previous installment of "Code Corner" focused on *NEC* Section 705.12(A), which covers supply-side connections for grid-tied PV systems. However, many residential and small commercial systems are net-metered and connected on the load side (typically via a back-fed circuit breaker in an AC panel) of existing service equipment.

Load-Side Connections

Section 705.12(D) establishes the requirements for connecting the output of a parallel power production system on the load side of service equipment. It allows this interconnection point to be at any distribution equipment on the premises, which makes it possible to connect to the utility grid in a subpanel rather than in the main AC service.

Section 705.12(D)(1) requires that each interconnection be made at a dedicated circuit breaker or fused disconnect. Section 690.15 allows for a single disconnecting means for the combined AC output of more than one inverter. This strategy is commonly used on larger systems that are connected on the load side: a dedicated AC breaker panel holds back-fed breakers from several inverters. The panel's combined output is interconnected on the load side of the AC service through a single, larger breaker.

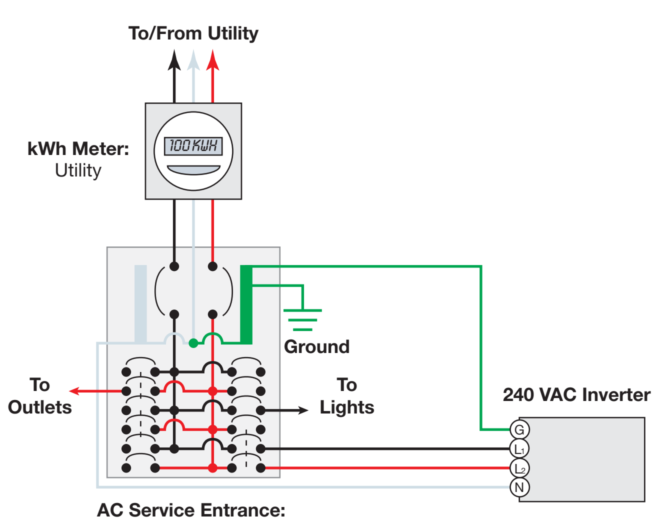
Brian Mehalic

A grid-tied PV inverter connected on the load side of the main AC service panel. In addition to the lockable disconnect and production meter required by the utility, there is a back-fed breaker in the main panel.

The 120% Rule

Section 705.12(D)(2) states that the sum of breakers supplying power to a busbar or conductor must not exceed 120% of the busbar or conductor's rating. Both the overcurrent protection device (OCPD) between the grid and the service panel (typically the main AC breaker) and the OCPD from the inverter(s) are considered power supplies.

Load-Side Connection



For example, an AC service panel with a 200 A main breaker and a 200 amp-rated busbar could have up to 40 A of inverter output-circuit OCPDs installed (200 A + 40 A ≤ 200 A × 1.2). Since Sections 705.60 and 690.8 require that the minimum inverter output-circuit OCPD be 125% of the inverter's rated maximum output current, the inverter or inverters in this example could have a total maximum rated output current of 32 A (40 A ÷ 1.25 = 32 A).

In some service panels, the busbars have a higher rating than the main OCPD, which allows installing more inverter output OCPDs (see table). In new construction, installing a service panel of this type will allow for a larger PV system to still be connected on the load side. And, though it is not always possible, in some cases, downsizing the main breaker is an effective strategy. For example, replacing a 200 A main breaker with a 150 A one would allow 90 A of inverter breakers to be installed (150 A + 90 A ≤ 200 A × 1.2). Load calculations must be performed to ensure that the new, smaller main breaker is large enough for the existing loads, and finding a smaller main breaker may be difficult or expensive. Additionally, replacing the main breaker in the main AC service requires shutting down the electrical service. In other cases, a service equipment upgrade may be the only option for a load-side connection and its cost should be weighed against the cost of a supply-side connection.

New to the 2011 *NEC* is an Exception to the 120% rule for grid-tied with battery backup PV systems. The inverter's battery charging and pass-through capability in these systems require the interconnection OCPD to be much larger than is required for a batteryless system. For example, a 3,000-watt, grid-tied battery backup inverter can draw 60 A from the grid for battery charging and pass-through to AC loads, but is only rated to deliver 25 A back to the grid. A 60-amp interconnection breaker can't be installed in a typical 200 A residential service without violating the 120% rule. Instead of basing busbar-loading calculations on the larger breaker size, the Exception now states that 125% of the rated utility-interactive current from the inverter be used. In this example, that would be 31.25 A (25 A × 1.25), which allows the inverter to be interconnected in a 200 A service panel.

Service Panel Amp Ratings

Busbar Rating	Main Breaker OCPD Rating	Max. Inverter Output-Circuit OCPD	Inverter Max. Rated Output
100	100	20	16
125	100	50	40
200	200	40	32
225	200	70	56
400	400	80	64

Load-Side Connections & GFP

Section 705.12(D)(3) requires that interconnection occur on the line side of all ground-fault protection equipment. The Exception allows load-side connections, but the ground-fault protection device (GFPD) has to be listed as suitable for backfeeding and protection must be in place for equipment from all ground-fault sources. For residential and small commercial systems, ground-fault breakers typically cannot be used for interconnection. Larger systems may require ground-fault protection as part of the main AC breaker per Section 230.95 (480Y/277 VAC services rated at 1,000 A or more). If this is the case, documentation may need to be obtained from the breaker manufacturer stating that the breaker can be back-fed. If it cannot, then a supply-side connection is the only option.

Breaker Requirements & Marking

When multiple sources can supply power to a piece of equipment, Section 705.12(D)(4) requires that the equipment be marked to indicate the presence of all power sources. Usually, the marking for the main breaker in a panel will be stamped into the metal cover. Additional labeling needs to be included at any panel where there is one or more breakers being back-fed by an inverter. This includes subpanels where the interconnection is, as well as the main service panel. Section 690.54 expands upon this, requiring that all points of interconnection be marked at their disconnect as a power source and with the rated AC output current and nominal AC operating voltage of the interconnected PV systems.

Sections 705.12(D)(5) and (6) detail requirements for circuit breakers back-fed by an inverter. They must be suitable for the application, and an Informational Note about the sections states that if the breakers are marked with a line and a load side, they cannot be used. Breakers connected to grid-tied inverters do not need additional fastening—clip-on breakers can be used because the inverter will immediately turn off if the breaker is pulled from the busbar per the UL1741 listing requirements, meaning no part of the breaker will be energized. However, in a grid-tied system with battery backup, an inverter output breaker supplying power to a backed-up loads subpanel needs to be fastened per Section 408.36(D). The breaker will remain energized as long as it is wired to the inverter, even when it is physically removed from the panel.

Finally, Section 705.12(D)(7) requires that when the sum of the breakers supplying power to a busbar exceeds the busbar's rating (as allowed per the 120% rule), that the breakers be located at opposite ends of the panel's busbar. For example, if the main breaker is at the top of the busbar and the sum of it and the inverter output-circuit OCPD exceeds the busbar's rating, the inverter OCPD would have to be located at the bottom of the busbar. A permanent label must be applied so that the inverter breaker is not moved in the future (see label sample, below).

WARNING:
INVERTER OUTPUT CONNECTION.
DO NOT RELOCATE THIS
OVERCURRENT DEVICE.

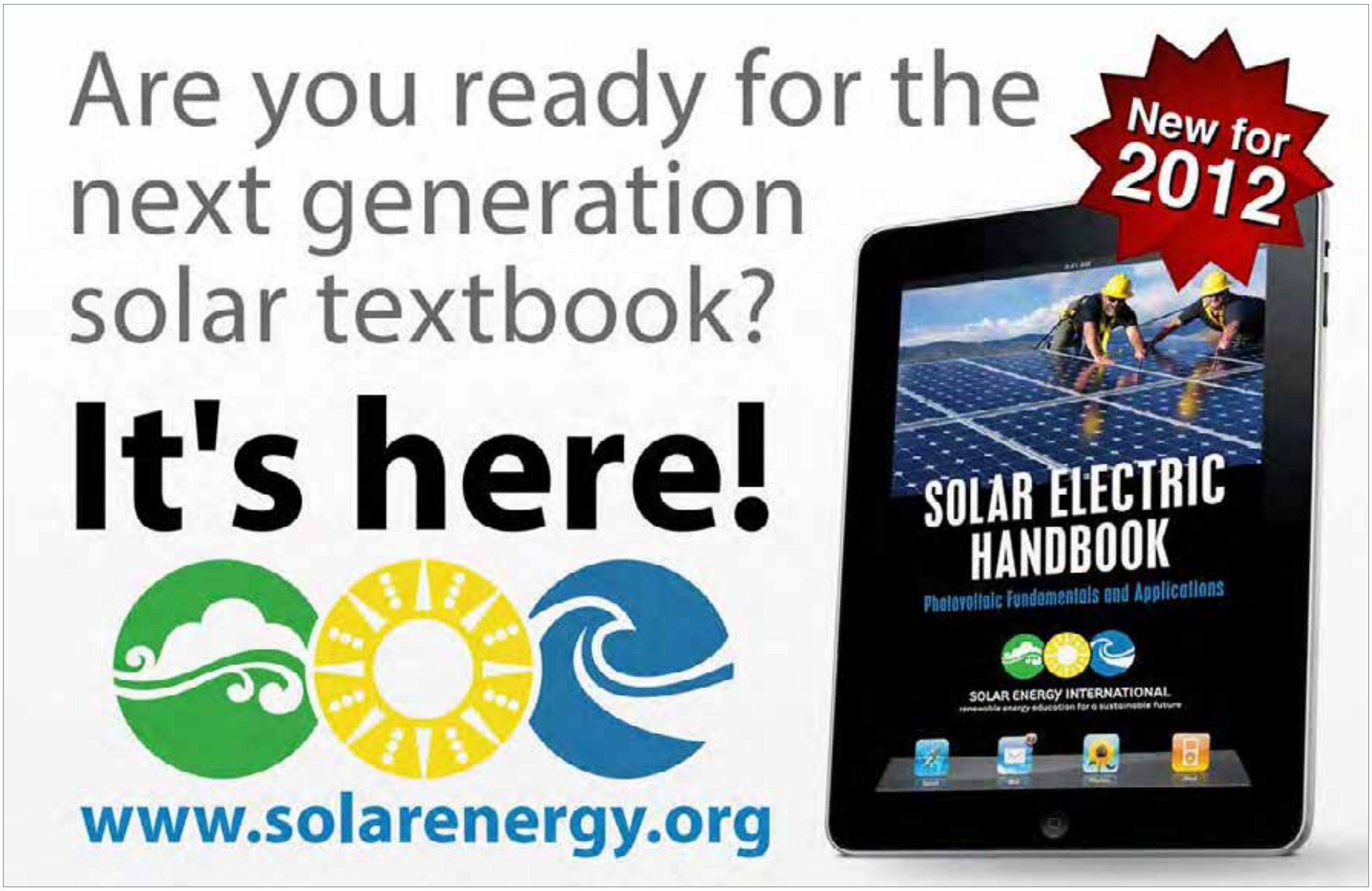
This rule applies equally to main service panels and subpanels, whether or not they have a main disconnect. Locating the breakers at opposite ends ensures that no point on the busbar will be subject to the full sum of the supply breakers—if they were adjacent to each other, then the section of the busbar below them could have to carry up to 120% of its rating.

There is no clear answer on how to accomplish this on service panels where the main breaker lies in the center, which is common in residences. In this case, consultation with the local AHJ will be necessary to determine if a parallel power production system can be interconnected on the load side. If not, a supply-side connection or service equipment upgrade will be required.

Section 705.12(D)(7) also clarifies that when the point of interconnection occurs in a subpanel, the first overcurrent device to which the inverter is connected should be used for calculations in all panels. This means that if there is a 20 A inverter output-circuit OCPD in a subpanel that is fed by a 100 A breaker in the main panel, the 20 A rating should be used for calculating the load on the busbar in the main panel.

Access

Brian Mehalic (brian@solarenergy.org) is a NABCEP-certified PV installer and ISPQ-certified PV instructor. He has experience designing, installing, servicing, and inspecting PV and solar thermal systems, and is a curriculum developer and instructor for Solar Energy International.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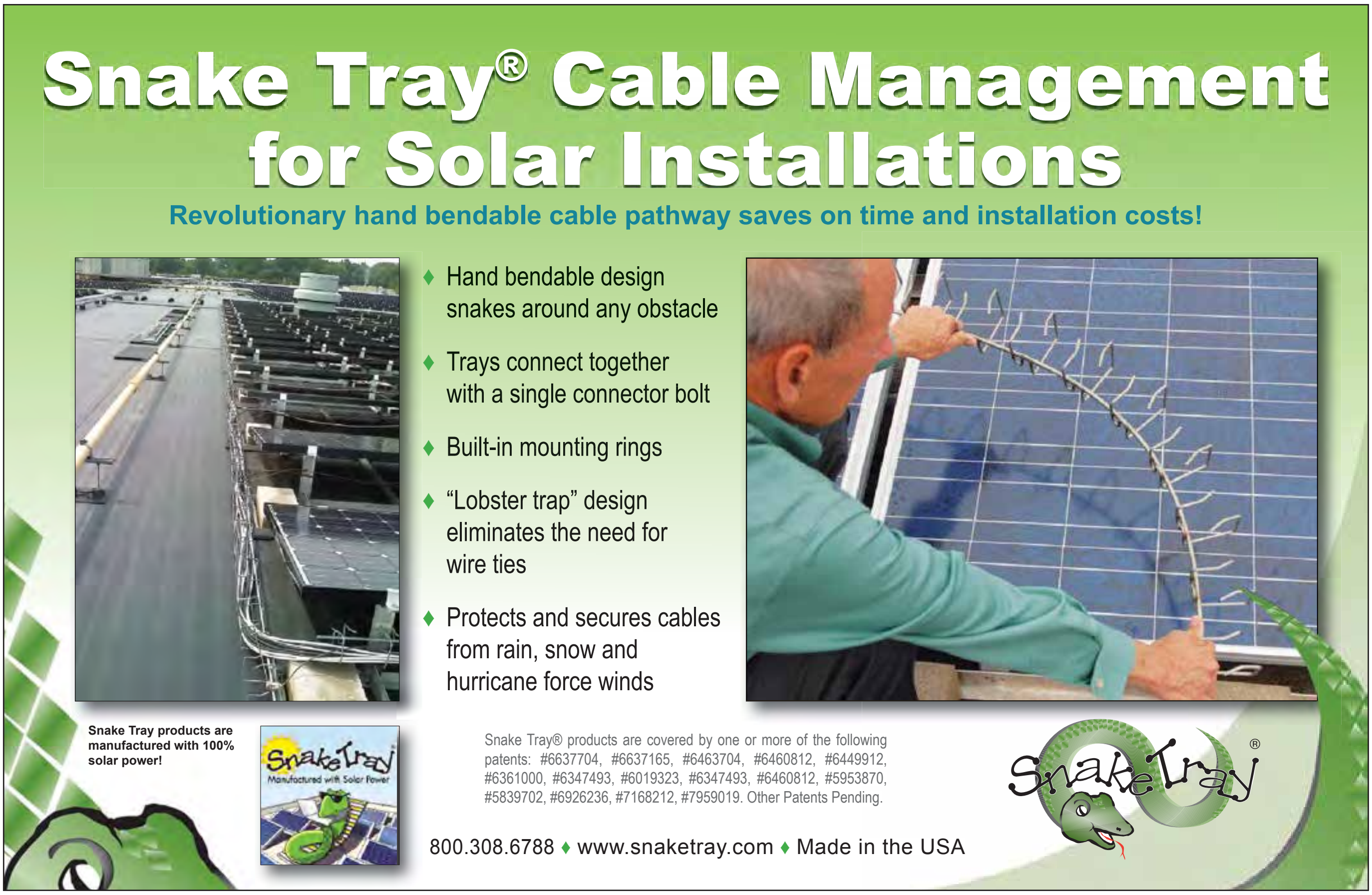
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Are We Preppers?

by Kathleen Jarschke-Schultze

Prepper: An individual or group that prepares for any change in normal circumstances.

I am enchanted with the burgeoning Prepper movement. I love reading about it. The show, "Doomsday Preppers," is my favorite guilty pleasure. I have so much in common with Preppers. But does that mean Bob-O and I are Preppers, too?

EOTWAWKI

First there are the associated acronyms to familiarize yourself with: EOTWAWKI (end of the world as we know it), BOB (bug-out bag), and you can probably guess "when the SHTF."

Many Preppers are preparing for a specific catastrophic event that would result in the EOTWAWKI. I hear a lot about the Mayan calendar's alleged date of December 21, 2012, being *the* one. I have also read that since the Mayans did not recognize leap years that date has already passed us by.

I'm reminded of the Y2K frenzy. As renewable energy providers, we spent a lot of time back then calming people and actually talking them out of extravagant purchases.

What About Us?

It seems that much of the Prepper activities are really just old-fashioned farm skills. I think that a lot of those skills are making a comeback. Witness the whole Prepper movement and the rising popularity of "nose-to-tail" butchery. When most of America lived on family farms, people would "put by" enough food for two years.

All that being said, I can't help but compare our life to a Prepper's. No, we don't have a bunker. But we do have a 20-foot-long steel container (dubbed "The Keep") buried in the hillside, which serves as food and sundries storage (see *HP140*).

Our garden is larger each year, providing a greater percentage of our food. The garden harvest is canned, dried, pickled, frozen, and fermented. I can now grow and successfully store enough carrots, onions, and potatoes to last through the winter. I only use open-pollinated seeds and save them from year to year. Next year, we'll begin the great pig experiment. I fully expect to learn a variety of old-fashioned ways to preserve meat and utilize those pigs to their full porky potential.

Five Principles of Preparedness

The American Preppers Network publishes the "Five Principles of Preparedness" on its website—here's how we fit into their categories.

1. **Thrift & frugality.** Having a good bone-yard and a nice selection of tools goes a long way. I like nothing better than repurposing a salvaged article into something I need.
2. **Self-reliance.** We provide and maintain our water sources for home and garden. We use wind, water, and solar power to run our "secure location."
3. **Independence.** We've always considered ourselves independent. Off the grid, off the pavement, and some people think, "off our rockers."
4. **Industrious.** You can't run a homestead or farm and not be industrious. It seems to be impossible for us to sleep in late. We always wake before sunup. And there is always a list of chores and projects to be worked on.
5. **A year's supply.** We grow, harvest, process, and store as much food as possible—while expanding our garden every year. I keep bees and chickens. We buy staple foods in bulk and store them in The Keep. Soon we'll be pasturing pork, then butchering it ourselves.

Tattl(er)ing

We were watching "Doomsday Preppers" one evening when they interviewed a woman standing in front of ceiling-to-floor shelves full of home-canned food. Curiously, the tops of her canning jars were white. We wondered what that was all about. So we searched the Web for "white canning jar lids," which led us to Tattler's reusable lids (reusablecanninglids.com).

Every year, I wait for canning lids to go on sale at our local store. Then I stock up on the regular and wide-mouth sizes. Every year, they are more expensive. Tattler appears to have the answer—fully reusable canning jar lids, in both sizes, made from white plastic with a thin rubber ring. Both parts are reusable.

Back in 1976, a canning lid shortage struck the United States. Seeing a need, a tool and die maker specializing in plastic developed the Tattler lid. There are two parts—the hard white plastic lid and the thin orange rubber ring. The hard plastic lid has a lifetime guarantee and the rubber ring can be reused as long as it retains its shape and has no tears or nicks. According to the user reviews on the company's website, people have been using them multiple years without a hitch.

Of course I bought some! So far, I have used them on jams and pickles. They work great, even though I had to change my canning routine a little. With these lids, you only tighten them finger-tight on the jar. After processing in a water bath or pressure canner, you lift out the jars and immediately tighten the lids as much as possible. Then you leave them to cool 24 hours, as you normally would.

Bob-O has done the math and by the third usage the lids will have paid for themselves. Then there is the added bonus of always having lids on hand when you need them, bypassing a hurried, unplanned trip to town (which for us is 50 miles). Thanks, Preppers.

Bugging Out

A lot of Preppers prepare to "bug out" to a secure location in the event of the EOTWAWKI. There are myriad available lists and instructions for stocking a bug-out bag. It seems you actually need two—a small one for your workplace (enough supplies to get you home), and a larger one to get you to your bunker or secure location. Well, we are already here—no need to bug out. The closest thing to a bug-out bag that I have is my winter kit for the car. Food, water, a wool blanket, tire chains, a plastic poncho, a rain suit, a large flashlight, and gloves are included. I'm thinking that would get me home safely.

Prepper Power

We have noticed a distinct lack of renewable energy in a Prepper's arsenal of supplies. Most seem to stockpile fuel of some flavor and a generator for electrical needs. Seems kind of shortsighted, especially since Preppers are striving for personal and household independence on a dramatic scale. Solar electricity and solar hot water would go much further—and be a lot quieter.

Having lived off-grid for more than 25 years, I know it just isn't that hard to do. Power-conserving measures become automatic very quickly. Where we live, we also need to conserve our water. Again, this all becomes second nature in a short time.

So are we Preppers? I think I would have to say yes. But we prep for our life as we want it to be. It is the life we continue working on to make ourselves practical and sustainable.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is growing heirloom Glass Gem Indian corn at her off-grid home in northernmost California.


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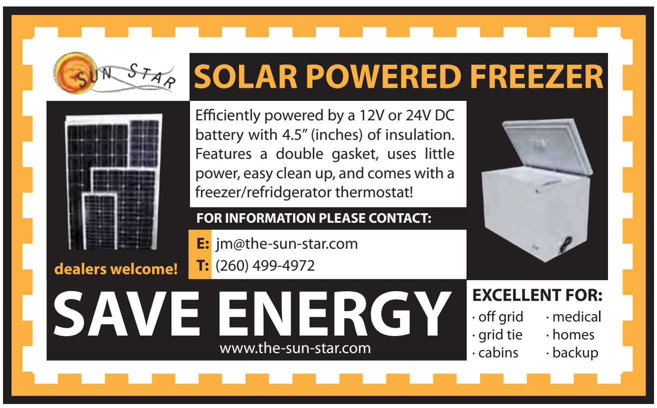
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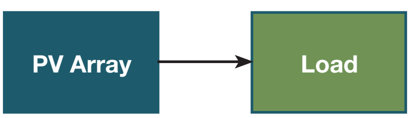
PV System Types

Solar-electric systems use photovoltaic (PV) modules to make electricity, for use by the electrical loads. Between the PV module(s) and the loads, there are a number of different components and configurations, although four basic configurations are common.

1. PV-direct systems are the simplest, consisting of a PV module or modules connected directly to a load. There may be electronic controls or a linear current booster between the two. Having no storage capability, these systems operate only when the sun is shining. Common applications are water pumping and ventilation.

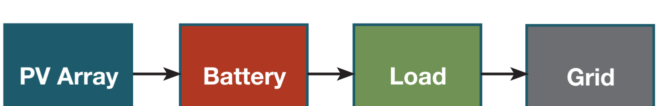


Photovoltaic (PV) modules.

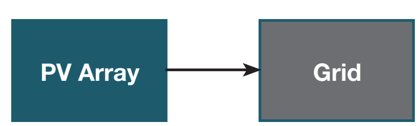
2. Off-grid or "stand-alone" systems pair PV modules with batteries for energy storage. This allows energy use when the sun isn't shining, like at night or during storms. A charge controller prevents overcharging the batteries; it can also protect against too deeply discharging the batteries. These systems usually have an inverter, which converts the DC electricity generated by the PV modules and stored in the batteries to conventional AC electricity so that common appliances may be used.

Off-grid systems must supply all of the energy needed, so they often include other sources to supplement solar energy, such as a fuel-fired generator, or wind or hydro generator. Users must learn to live within their energy budget, since there is a limited supply.

3. Battery-based grid-tied systems are similar to stand-alone systems except they can use the grid for "selling" surplus energy (and earning credits for future use—net billing) and for backup battery charging. With these attributes, battery-based grid-tied systems have the best of both worlds. However, they are more complex and more expensive than batteryless grid-tied systems.



4. Batteryless grid-tied systems are connected to the utility. Compared to battery-based systems, they are simpler, more cost-effective and environmentally friendly, and require the least maintenance. Their drawback is that when the utility grid is out of service or out of spec, they cease operation until the grid problem is resolved. These systems usually have one major electronic component—the batteryless inverter, which converts the PV output to usable electricity for your home or for sending back to the utility. More recently, microinverter-based systems—in which an inverter is matched to each PV module—and AC modules (which incorporate a microinverter onto the module) have gained a foothold in the market. Microinverter-based systems are especially suitable in areas where partial shading of an array is a concern.



Most new systems installed in the developed world are batteryless grid-tied systems. Whether to have backup or not is a practical and personal decision, based on the number and duration of outages in your area and your personal preferences and needs.

How you use solar electricity depends on your application and your personal choice. One of the four configurations above will best serve your needs, allowing you to use the solar energy that comes up every morning.

—Ian Woofenden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