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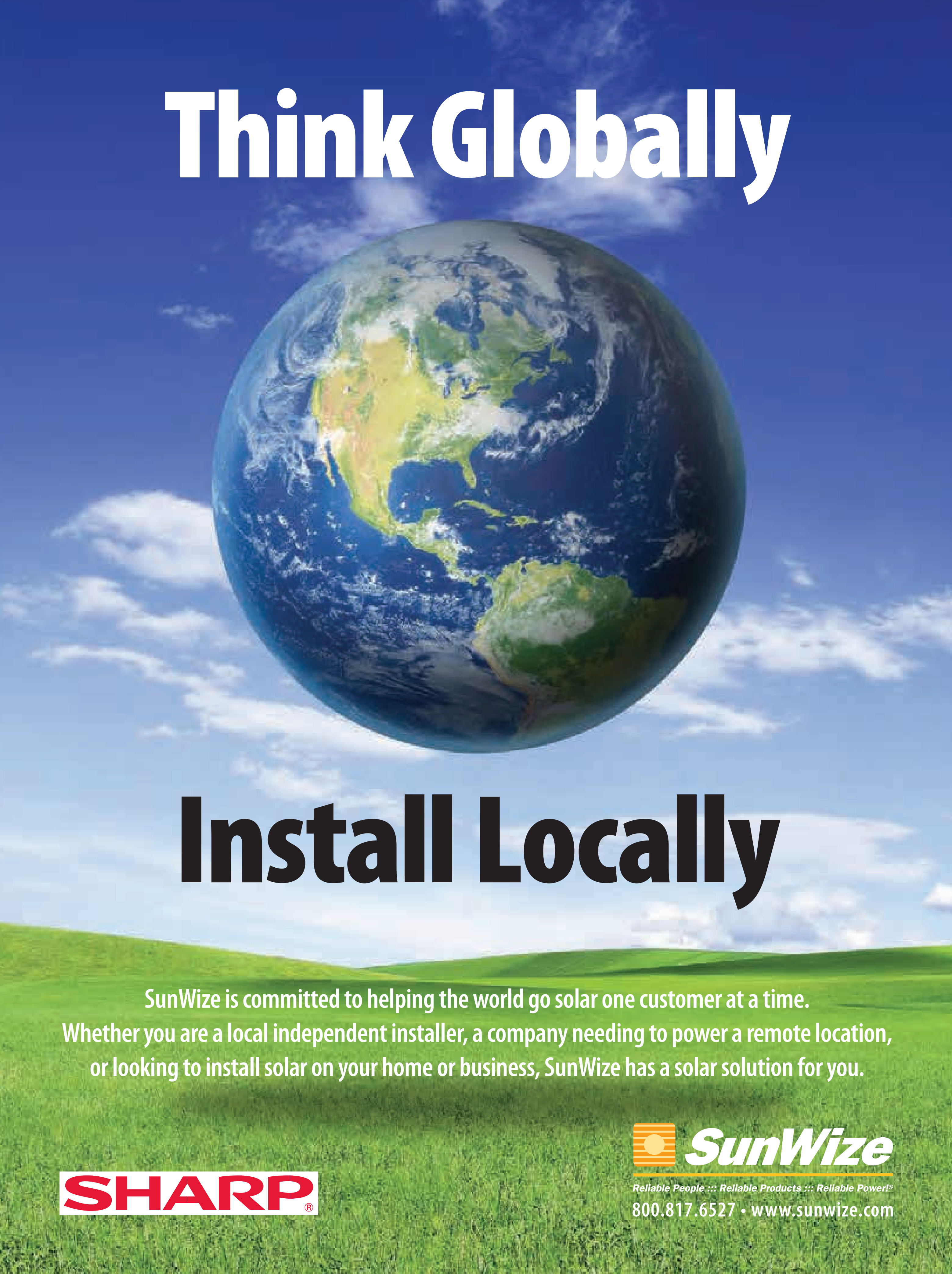
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February & March 2010

Photos (clockwise from bottom left): Benjamin Root; www.photoman.com; Donna Dolan (2); Stephano Paltera; Holly Noel; Roy Butler

On the Cover

Bradley Berman recharges his newly converted plug-in hybrid-electric Toyota Prius.

Photo www.photoman.com

Regulars

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New Minds Advancing RE

Courtesy www.seia.org

Attending international solar energy conferences provides a crash course on the current state of solar. In 2008, I couldn't get over the industry's staggering growth. The large, fancy displays and new folks in suits and ties made me a little suspicious about industry directions, and left me feeling a bit nostalgic for the "good ol' days," when the displays were simple and straightforward (no glitz!) and it seemed like all the players were part of one big, happy (and casually dressed) family.

This past year, however, I came away from the conferences with a new appreciation for the next generation of folks representing the solar industry. While they do not carry years of experience in the industry and were not around for the early years of slow, steady growth, many of them are coming in with incredible backgrounds and talents that are needed to push the solar industry into a new age. For example, a large number of people are making a transition from the computer industry into designing and producing specialized solar products—and with access to the venture capital that had previously been the hallmark of the computer industry.

This is good news, as these smart people helped catapult the world into a new age of information technology and have now set their eyes on clean energy. They see massive opportunity in the growing demand for solar and seem to be coming up with new and inventive ways to improve system design, measurement, and performance. It is exciting to see their results: slick system design software that can help determine module layout and can be incorporated with site assessment data to predict system output; online array- and module-level data monitoring systems; new hardware to aid installers in checking system output before commissioning; plus lots of solutions to reduce shading impact via module-level MPPT devices—to name just a few.

It is an exciting time indeed to be a part of the home power industry, and it's great fun to connect the dots between the newbies and their innovations and the existing solar bozos who have been working in the industry for decades, honing their solar skills. We're right there with them, integrating the old and the new, working together to advance solar into a new age.

—Justine Sanchez for the *Home Power* crew

Think About It...

"We simply must balance our demand for energy with our rapidly shrinking resources. By acting now, we can control our future instead of letting the future control us."

—Jimmy Carter

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Getting Smart

Microsoft and Google Plug Into the Energy-Monitoring Market.

Tech giants Microsoft and Google are testing Web-based applications that help consumers monitor their energy consumption and make more informed energy choices. The accuracy of the predictions and energy savings produced by both services remains to be seen, but early indicators suggest that these tools may prove valuable in helping utilities meet state and federal energy conservation requirements.

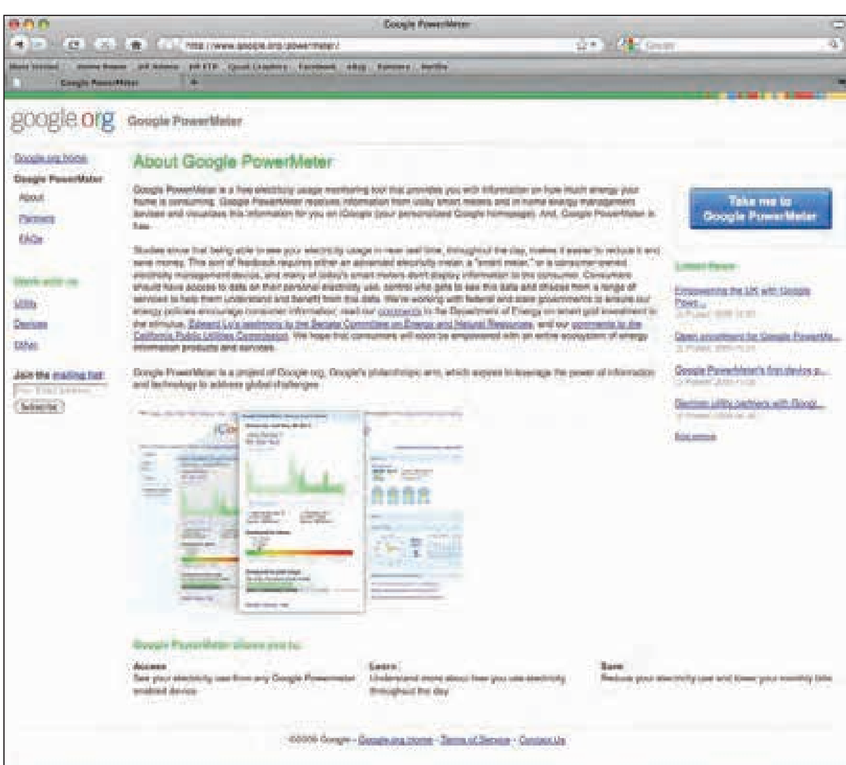
Google PowerMeter

www.google.org/powermeter

The Backstory Currently in beta-testing mode, PowerMeter is a free opt-in service that interacts with "smart meters" or electricity management devices provided by utility companies. Google launched the prototype service last spring, partnering with a select group of utility companies to test the application's capabilities. PowerMeter is currently available to a select group of utility customers—including San Diego Gas & Electric in California, TXU Energy in Texas, Wisconsin Public Service, and White River Valley Electric Cooperative in Missouri. Utility companies in the United Kingdom, India, Canada, and Germany are also testing the service for large-scale application.

How It Works PowerMeter allows consumer households equipped with a smart meter to monitor their electricity usage and greenhouse gas emissions through an iGoogle widget, or a personal Google homepage. The software retrieves data from the smart meters and processes it to aggregate energy use over time. The service also compares the consumer's energy consumption with that of friends and neighbors—employing a "keeping up with the Joneses" approach to encourage homeowners to reduce their energy use.

Limitations The electric utility company must provide smart meters for its customers, and then take the initiative to become a PowerMeter partner. So far, Google has no plans to expand the PowerMeter service to gas or water utilities. For now, the application does not provide appliance-specific data or have built-in remote control options.



Microsoft Hohm

www.microsoft-hohm.com

The Backstory Administered by Microsoft's Energy Management and Home Automation Group, Hohm is a free online tool that allows consumers to keep tabs on their monthly electrical power and gas usage. (A plan to integrate water consumption is in the works.) Since the launch last summer, the software giant has partnered with four utility companies: Seattle City Light, Sacramento Municipal Utility District, Xcel Energy, and Puget Sound Energy. The Web-based application is built with the energy models used in the Home Energy Saver tool developed by the Lawrence Berkeley National Laboratory (LBNL) and the Department of Energy (DOE).

How It Works Anyone with a Windows Live ID can use Hohm, but customers of a Hohm-partner utility have the added advantage of

automatically uploading their current energy usage and historical data, which aids in the generation of a more accurate energy use predictions and recommendations. To get started, consumers simply log in and complete a questionnaire regarding their household circumstances (e.g., number of occupants, appliances, and systems). The more information entered, the more accurate the energy report produced. Personalized energy-saving recommendations are generated based upon local and national trends, the information provided in the questionnaire, and when available, usage data downloaded from a utility partner. Such recommendations can range from replacing furnace filters and installing programmable thermostats to sealing air leaks with caulking and weatherstripping. A basic pie chart shows how much the homeowner will spend on heating or cooling versus other uses, and comparisons measure the consumer's energy usage against that of others in the area.

Limitations Since Hohm is a revenue driver, Microsoft is selling contextual ads and might broker information between customers and utilities. Since Hohm uses the Home Energy Saver energy models, it's not exactly a pioneering technology, and it remains to be seen how much it will differentiate from this widely used, self-auditing option. Though Hohm does not currently interface with smart meters, Microsoft plans to use the service as a gateway into the device monitoring market, ultimately working with thermostat manufacturers, utilities, and developers of "smart plugs" to add energy systems controls and provide more specific data on energy consumption.

—Kelly Davidson

Solar Credentials

Certified, *certificate holder*, *accredited*, and *licensed*: These and others are terms you've probably heard used to describe the credentials of solar installers or organizations. But if you're like most folks, you probably don't know what to make of them—or which terms are most meaningful when evaluating the credentials of a solar installer. But a quick tutorial in the terminology will give you all the confidence you need to choose a solar installer.

A person is **certified** upon completing a certification process, typically through an employer, vendor, or independent agency. Most certifications require a candidate to complete prerequisites (i.e., courses, training, experience) before taking a written examination. Such requirements and tests often follow standards set by the International Organization for Standardization (ISO), a non-governmental organization that works with other institutes to develop international standards for various fields. In general, the most credible and valuable certifications are those awarded by an independent agency.

The PV installer certification program administered by the North American Board of Certified Energy Practitioners (NABCEP) is one example of an independent, professional certification. The NABCEP program adheres to requirements established by internationally recognized standards organizations such as the American National Standards Institute. NABCEP certification exams and job analyses are kept current through a process in which committees of volunteer experts meet regularly to revise questions and skills assessments. In addition to demonstrating actual field experience, a NABCEP-certified installer must pass a rigorous exam written by leading, respected experts on PV and solar thermal technology.

To qualify to take the NABCEP certified installer exam, a candidate must show that they have at least 40 hours of advanced training specifically in PV (or solar thermal, for that exam). In addition to the educational requirements, a candidate must demonstrate that they have been the person responsible for at least two installations. In some jurisdictions, installers must be NABCEP-certified (or on their way to becoming certified) to work legally and qualify for grant programs, feed-in tariffs, incentives, and/or tax credits. Note: A NABCEP-certified installer is identified by a unique certification number and can be found in the national directory of Certified Installers via the NABCEP Web site (www.nabcep.org).

Besides NABCEP, several educational providers, and product manufacturers and vendors now offer various certifications and certificates. SunPower Corp., for example, trains and certifies its dealers in the installation of its building-integrated PV systems. Typically, private-sector certifications have their own set of standards, rather than adhering to third-party standards.

A **certificate** is generally awarded for completion of a specific program, course, or exam. There are a wide variety of certificate training programs available at the entry level. Some run as long as 400 hours for beginner, while others span only few days and are geared toward skilled professionals who are adding to their existing knowledge base. NABCEP's *certificate*—not to be confused with its more rigorous *certification* process—indicates that an individual has demonstrated a basic knowledge of PV systems and is qualified only for a supervised, entry-level position with a solar installation company.

Licenses are awarded by government agencies and are almost always mandatory, requiring a periodic fee to maintain them. For example, the State of California requires both solar thermal and PV installers be licensed contractors through the California Contractors State Licensing Board. According to the California Energy Commission, "qualified contractors are your key to getting the most productive PV system for your home or business," so be sure to follow up with the local or state licensing office. Many have searchable databases, where you can check to see if your installer is licensed, how long they've held their license, and even how much liability insurance coverage they carry. Working with someone who is not properly licensed can negate your coverage under some homeowner's insurance policies, and disqualify you for local incentives and rebate programs.

An electrician may be licensed, but that does not mean they are adequately trained in the specifics of installing solar-electric systems. The requirements for professional practice vary from state to state and sometimes by city, so check with your local authorities and become informed about any specific requirements.

Then, consider your installer's other credentials and ask for—and contact—their references. As a general rule, it is best to choose PV or solar thermal installers who have all the necessary licenses, permits, and trade qualifications required in your jurisdiction. Currently, the NABCEP certification is known throughout the industry as the "gold standard." Ultimately, you'll have to draw your own conclusions about who to hire, but when it comes to choosing a solar installer, knowledge is power.

—Ezra Auerbach (eauerbach@nabcep.org) has been actively involved in the renewable energy industry since 1986 and is currently the executive director of the North American Board of Certified Energy Practitioners. His connection to renewable energy is professional and personal, having lived and worked off-grid for more than 35 years.

As a general rule, choose PV or solar thermal installers who have all the necessary licenses, permits, and trade qualifications required in your jurisdiction.

Shawn Schreiner

What it Means to be Accredited

Accreditation is awarded to educational programs and testing laboratories by non-governmental agencies. To achieve accreditation, organizations must meet predetermined standards mandated by the accrediting agency.

Currently, 20 renewable energy training organizations, nine master trainers, and 16 instructors have received accreditation from the Institute for Sustainable Power Quality (ISPQ), a nonprofit organization that develops and maintains international standards for renewable energy training providers. Such accredited organizations have been vetted by ISPQ to ensure that their course, staff, and facilities meet their standards. To learn more about what is involved for a training organization or trainer to gain accreditation or certification from ISPQ, visit the Web site at http://irecusa.org/irec-programs/ispq-training-accreditation/.

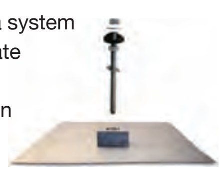
Anyone seeking education in the field of renewable energy would be well advised to make sure that their instructor is ISPQ certified...

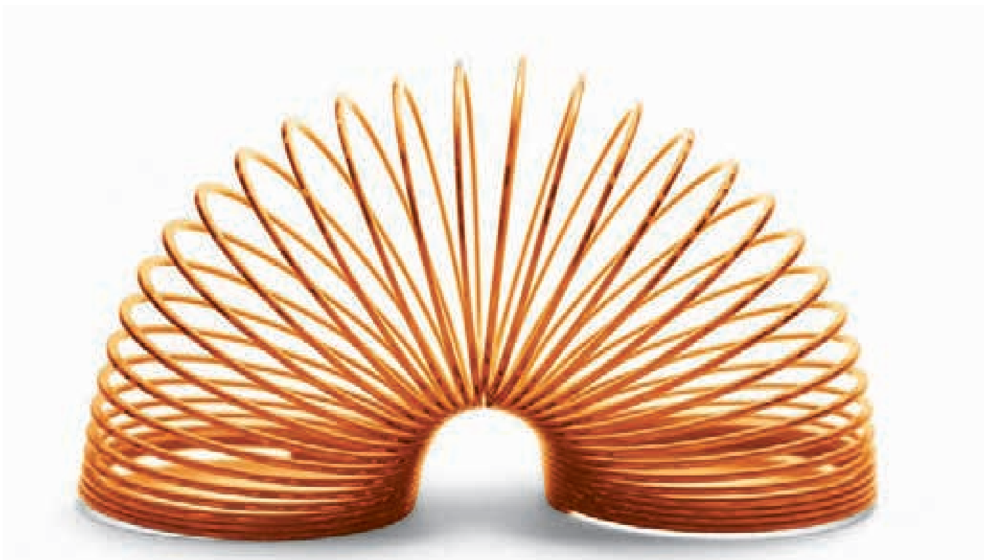
ISPQ offers accreditation to training programs and continuing education courses and also offers certification to trainers and instructors. Anyone seeking education in the field of renewable energy would be well advised to make sure that their instructor is ISPQ certified and, if possible, that the training organization was also accredited by ISPQ.

S.U.N. Equinox Combination Thermal Storage Tank & Kit

Solar Usage Now (www.sunequinox.com), based in Harlan, Indiana, rolled out its S.U.N. Equinox Heating System, which includes an on-demand gas-fired instantaneous water heater paired with an SHW storage tank. The water heater is available in 79- and 132-gallon models, equipped with either one or two heat exchangers. One heat exchanger can be used to heat domestic hot water, while the other can be used for space heating systems. (The larger model is also available with only one exchanger for single-use applications.) The corrosion-resistant, all-plastic tanks are unpressurized, making them suitable for drainback solar systems. At 2 feet square and 5 feet tall, the 79-gallon tank occupies a small footprint and, at 121 pounds, is fairly easy to maneuver into place. The 132-gallon tank is slightly larger at 30 inches square and 5 feet tall. It tips the scales at 192 pounds, with the single exchanger model weighing 179 pounds. Three inches of foam insulation help slow heat loss through the tank walls. Two Grundfos pumps circulate the water from the storage tank to either the on-demand heater or to Apricus evacuated-tube collectors or Solarhot USA flat-plate collectors.

—Chuck Marken





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SMA Sunny Boy High-Frequency Inverters

Courtesy www.sma-america.com

SMA America (www.sma-america.com) is introducing their next generation of grid-tied inverters, a high-frequency Sunny Boy—UL pending and expected in the first quarter of 2010. The high-frequency transformer design reduces the inverter weight to less than 50 pounds—more than 30 pounds lighter than existing, similarly sized SMA inverters.

Besides lightening up, the inverter has also slimmed down, allowing for recessed wall mounting between studs. SMA's flush-mount kit consists of a vented metal pan, which gets mounted in a stud-framed wall. Input and output wiring can be pulled into the pan and the wall finished. The wires can then be pulled into the inverter housing as the inverter is inserted and mounted into place, and final wiring connections made. The Sunny Boy HF inverters include 2,000-, 2,500-, and 3,000-watt models. These inverters have "automatic grid detection," which allows the inverter to output either 240 or 208 VAC (for commercial buildings) without requiring any field modifications. Other design features include an integrated, lockable DC disconnect and the ability to configure the inverter for positively grounded arrays.

SMA Sunny Beam with Bluetooth offers wireless data monitoring for up to 12 Sunny Boy inverters. The Sunny Beam records and stores up to 100 days of system data, which can be transported to a PC via a USB port. It has a built-in PV cell to keep its battery charged (it can also be charged via the USB port) and has an audio alarm to alert users of a problem with the PV system.

—Justine Sanchez

Citel Surge Protection

Citel Inc. (www.citel.us) has introduced a line of UL-recognized surge protectors built to help guard PV systems against direct and indirect lightning strikes. The DS50PV surge protection device can be mounted on a din rail inside an inverter or DC combiner box. The DS50PV is available in system voltages of 500, 600, 800, and 1,000 VDC. It uses a metal oxide varistor (MOV) protection circuit and DC thermal fuses to handle high surge currents up to 40 kA 8/20 µs. Status of the protector is shown by a visual fault indicator and an optional set of dry contacts can provide remote signals. These devices incorporate a replaceable protection module that can be replaced without having to unwire the surge protector from the system. Citel also offers a line of surge protectors for the AC distribution panel and an inverter's AC output, signal communications, and condition monitors.

—Justine Sanchez

Courtesy www.citel.us

The Clothesline Comeback

Courtesy www.laundrylist.org

If Alex Lee has his way, the clotheslines of yesteryear will once again find a place in every backyard in America—yes, even at the White House. His organization, Project Laundry List (PLL), is a force behind the national movement that promotes air-drying and cold-water clothes washing as a simple and effective way to conserve energy and reduce greenhouse gas emissions.

Grassroots educational and advocacy campaigns bearing clever laundry puns—"Stop the Plants! Hang Your Pants!" and "We're in hot water, if we don't use cold!"—have put a lighthearted spin on the cause, but the urgency for altering the American way of doing laundry is no joking matter, according to Lee.

"We're the only country in the world that spends more than 6% of our electricity bill on clothes drying and relies on the tumble dryer for most of our clothes drying," says Lee, a former attorney who quit his day job to run the organization full time. "And what's most frightening is that we've developed this misguided thinking that energy and resource efficiency will solve all of our energy problems, but it's not enough to be efficient. We need to change our behavior."

Since its start in 1995, the nonprofit group has been helping communities get the word out with events and activities ranging from clothesline art exhibits to drying-rack design competitions.

On a national scale, the group recently launched an online petition requesting that the Obama family line-dry their clothes on the White House lawn, as former presidents have done in the past. The hope, Lee says, is that the White House will set an example for the rest of the country and the world.

"The thing that keeps me up at night," Lee says, "is that every person in China, India, and the rest of the developing world wants what we have and may someday trade in their clotheslines for dryers. And when that happens, it is not going to matter how energy efficient the dryers are."

In addition to pushing for widespread adoption of clotheslines, the group champions for cleaner energy alternatives, such as small hydro-electric, solar, and wind projects. The group has also played an incremental role in instituting cold-water laundry washing practices in Missouri and New Hampshire state prisons.

But the real cornerstone of the group's ongoing work is its "Right to Dry" campaign, which aims to stop the bans on clotheslines imposed by some homeowner associations, zoning laws, and landlord restrictions across the country. The group partnered with the Community Associations Institute to help develop and implement rule changes that will allow residents of community associations nationwide to hang their clothes and participate in other "green" activities. Most recently, Lee provided testimony that helped Democratic Senator Richard McCormack include a "Right to Dry" provision in Vermont's energy bill that passed last year.

The standard that all states should strive for, Lee says, is the Florida law that allows clotheslines everywhere. Utah, Maine, Colorado, and Hawaii have passed similar laws, while another five states are considering measures that will also prohibit sanctions against clotheslines.

"But the real problem," Lee says, "is not the millions of Americans who are prohibited from hanging their clothes outside, it is that people refuse to take the time to do an essential task that will save energy. Using clotheslines and drying racks instead of gas or electric dryers is something easy and affordable that we can do. So why shouldn't we?"

—Kelly Davidson

The Laundry List

- About 5.8% of residential electricity use goes toward mechanical clothes drying, according to Department of Energy statistics from 2001.
- A recent Michigan State University study concluded that Americans could cut U.S. carbon dioxide emissions by 7.4% by 2019, with 17 simple practices, such as hanging clothes to dry, carpooling, and buying fuel-efficient vehicles.

To learn more or support one of Project Laundry List's programs, go to: www.laundrylist.org.

Courtesy Sarah Lozanov (2)

Wedded to Solar

When soon-to-be betrothed Kiril Lozanov and Sarah Lozanova sat down to create their wedding gift registry, they quickly came to the conclusion that the only thing they really wanted was a PV system.

At the time, they both worked for an Illinois renewable energy installation company and they were, Sarah says, "eager to walk our talk."

"We were both really concerned about climate change and all the fossil fuel that is being used," says Sarah. "And we knew that the technology to offset our utility electricity with solar power was available, although it wasn't highly affordable."

So they got creative and leveraged their upcoming nuptials to finance the system. "We created a Web site for our wedding registry, with the PV system listed as our main wish," says Sarah. She says that many gift-givers were very excited about helping them harvest the sun. After their gifts and federal and state incentives were totaled, Sarah and Kiril were left with only a small tab. Their RE industry connections entitled them to a discount, reducing the system cost to about $12,300. They also tapped into a 30% state rebate ($3,700) and a $2,000 federal tax credit. That, plus about $2,500 in gifts brought the net cost to about $4,100.

But financing their dream was only a part of achieving it: The fact that they lived in a condominium was, Sarah says, a major hurdle, since they'd have to get the board's approval to install a rooftop system. Even though the flat roof had excellent solar access, owners had no specific rights to place a PV system there. Undaunted, they pursued their plans anyway, and submitted them to the board for approval. They were happily surprised when their request for a PV system was approved, with only two stipulations: the PV array's mounting hardware couldn't penetrate the roof and only the DC disconnect could be placed on the building exterior. The other components had to be located in their unit.

Kiril installed the system with help from friends. The system uses ballasted pans to avoid roof penetrations, which allows removal for roof maintenance. Wiring from the modules is routed through exterior conduit and into their condo on the second floor. The system subpanel was located in the unit's hallway with conduit run through the kitchen wall.

The couple's system was designed to generate just over 100% of their estimated annual use, based on past bills. And, with mindful use and energy-efficient appliances, the system meets that goal.

PROJECT: Lozanovi residence

System type: Residential grid-direct PV on a three-story, 16-unit condominium

Installer: Kiril Lozanov, renewable energy specialist

Date commissioned: November 2007

Location: Chicago, Illinois, 42°N latitude

Solar resource: 4.4 average daily peak sun-hours

Array capacity: 1.66 kW STC

Average annual production: 2,000 kWh

Average annual utility bill offset: 100%

EQUIPMENT SPECIFICATIONS

Modules: Eight, Sharp 208 W

Inverters: Sunny Boy SWR 1800, 1.8 kW rated output

Array installation: Ballasted pan mounts on a flat roof, custom built; tilt adjusted manually each season between 25° and 55°

Testing SHW System Antifreeze

The antifreeze solution in a closed-loop solar water heating system can last decades—if it isn't abused. So it's smart to test it every half decade or so to ensure that the solution is in good condition.

The chemical companies that make the heat-transfer fluid—propylene glycol—add buffers to the mixture to lower its acidity. The buffers give the glycol a wider margin of safety before it will become acidic from heating. Temperatures above about 285°F break down the buffers in most brands of propylene glycol, with the exception of Dowfrost HD, which is rated to 325°F.

On the pH scale, 7 is neutral and anything below that is acidic. A glycol mixture that drops below a pH of 7 is a cause for alarm and solutions below a pH of 6.4 will start to corrode the tubing in solar collectors and their pipes. This is first evidenced by pitting and, eventually results in pinhole leaks.

You need to go back to chemistry class for your testing tools. Litmus paper and its color chart make a low-cost tester that can easily be purchased online. The litmus test requires just a drop or two of the solution, easily obtained by slightly opening the drain/fill valves on antifreeze-based systems. The litmus paper will react to the glycol, turning a particular shade that, when read on the color chart, indicates the solution's pH.

Courtesy Chuck Marken

A glycol mixture that drops below a pH of 7 is a cause for alarm, and solutions below a pH of 6.4 will start to corrode the tubing in solar collectors and their pipes.

A more expensive—but more accurate—tool is a pH meter, which gives a digital readout accurate to tenths on the pH scale. You'll need a little more of the glycol solution to immerse the meter tip, but the test is also easy and quickly accomplished.

Neglecting to test the pH of the solution in an antifreeze-based solar water heater has ruined many collectors. For each whole digit on the pH scale, the acidity rises or falls by a factor of ten. Any antifreeze system solution that's close to a pH of 7 should be changed.

It is also a good idea to check the freezing point of the solution unless you are sure of the antifreeze content. An inexpensive propylene glycol tester—a tube filled with tiny colored balls that float, depending on the freeze point—is used. The testers look exactly like those used to test car antifreeze (ethylene glycol), but are made specifically for propylene glycol. Auto supply stores usually stock them as the brand name Sierra, a company that makes propylene glycol.

If testing indicates the solution no longer provides freeze protection to the level you need in your climate, it's time to drain some of the solution and add more propylene glycol. In mild climates, a 30% solution (30% glycol; 70% distilled water) is typically used, which gives freeze protection to within a few degrees above 0°F, and burst protection to -20°F. But in most of the United States, a 50% solution is common, which gives freeze protection to -30°F and burst protection to -60°F. Extremely harsh winter climates call for a 60% solution.

—Chuck Marken


Trojan
2 VOLT
L16RE-2V
RENEWABLE ENERGY
Trojan
DEEP-CYCLE
GEL
Trojan
27-AGM
CYCLING AGM
12 VOLT
Pb

PV SYSTEM LONGEVITY

One of the things I don't see very often in the magazine is information about the durability of a solar-electric system. My wife and I have lived in the mountains of eastern Washington for more than 30 years. Our solar-electric system is 25 years old and we have had zero trouble with it other than two changes of batteries. The system consists of 16 Siemens M55s, a Heliotrope CC-120 charge controller, and a Trace 2012 inverter. I adjust the modules manually—they are on pole mounts—and have a Cruising Equipment amp-hour +2 meter to monitor battery state of charge.

Our location, about 20 miles south of the Canadian border, is in a harsh climate with temperatures swings of 50°F and lows of -30°F common. We heat with wood, and have a wood-fired water heater. Cooking and refrigeration are propane (a 50-year-old Servel). We have a backup generator, a 30-year-old Onan 4 kW, which we use if necessary during the winter to recharge the batteries. Total propane usage is about 250 to 300 gallons a year, depending on how much I need the generator for a table saw, planer, and other such tools.

Our system is still going strong, and I have seen no drop in electrical production. Ours is out of date, small, and immeasurably less expensive than the systems your magazine typically features, but it still works like new!

William Ebrecht • via e-mail


Courtesy Brent Summerville

APPROPRIATE TECHNOLOGY

I really enjoyed the "Appropriate Technology for the Developing World" article in *HP133*. It brought back a lot of memories from work we did in Nicaragua with Appalachian State College students at the Finca Esperaza Verde. I travelled with the first group and we had a blast installing a hydro system to help generate more energy during the wet season (they had an existing small PV system). We found the Nicaraguan folks to be happy and friendly. I think your statement summed things up nicely: "And if a good job is done, the systems will be an example for others in the community and beyond." No doubt.

Subsequent groups have helped install solar showers, study coffee pulp waste for biofuels generation, and convert a manual coffee bean depulper into a hydro-powered wonder-machine. The group did such a nice job, and the depulper machine worked so brilliantly that the farm manager shed tears, since this will save them so much hard labor.

Brent Summerville, Appalachian State University
• Boone, North Carolina

ENERGY & BIRDS

A recent study by Benjamin K. Sovacool (www.spp.nus.edu.sg/Faculty_Benjamin_K_Sovacool.aspx) points out that fossil and nuclear electricity generation actually kill 17 times more birds than wind farms (per gigawatt-hour), yet some still decry wind electricity for the few birds it does kill.

But the big point that seems to be missed is that the public has never stopped to think that birds might be getting killed by fossil and nuclear energy in the first place, let alone more than are killed by wind. And this presents an opportunity to fight fire with fire. Fossil and nuclear kill more birds than wind via:

- Bigger collision structures than wind turbines
- Collision structures low enough to touch flight paths
- Poisoned water at uranium and coal extraction sites
- Destroyed habitat from mountaintop removal & valley fill
- Destroyed habitat from heated river water (nuclear cooling)
- Destroyed habitat from emissions & food-chain poisoning

Newer wind turbines:

- Are much bigger, so they spin much more slowly
- Are much higher and out of bird flight paths
- Can be placed in less sensitive habitats than older turbines
- Towers don't use lattice framing that birds can perch on

Wind turbines on flat, desolate lands or miles offshore in the wind-rich Great Lakes (completely out of sight) won't affect birds the way mountain-ridge installations with older designs do. Newer, safer designs replace old equipment when it's time.

Now, when somebody says, "Wind kills birds," we know what to say: Some birds do die from wind. Many more die from fossil-fuel and nuclear energy.

Mike Cohn • Environmental & Consumer Advocate

Courtesy Lee Calhoun

SHADING CONCERNS

I was very excited to see the article in *HP133* on maximizing PV performance. We are in the process of designing and installing a grid-tied system for our existing home. I have been bothered that some installers don't seem to have embraced the mind-set that solar-electric modules are expensive—and therefore need to be squeezed for every possible kilowatt-hour of output. Seeing the information on microinverters and module maximizers to improve total system output was refreshing.

However, the picture of the off-grid New England house with the chimney shadow on the array was disheartening. Based on a crude test we ran at my installer's office, that chimney location can be costing as much as 15% to 20% of the affected strings' output for a major portion of the day! We held a 12-inch square piece of cardboard over one corner of one module in a large array, and saw performance drop 30% to 40% depending on the insolation.

Because of our conclusions and my imperfect site, I decided it use Enphase inverters, which not only minimize shading losses on my array, but give me detailed information about how each module is performing.

Lee Calhoun • Sodus, New York

TRUE SOUTH

I've read a few pieces in your magazine about finding true south, and wonder why it has to be so complicated? You can find true south easily on any Internet-connected computer.

Download and run Google Earth, locate your home, and make sure the compass in the upper right is pointing straight up to north (double-click on the "N" and it will automatically reset to true north). Print your location and draw a vertical line through the center of your desired installation. The top will be true north and the bottom will be pointing true south.

You can also show latitude and longitude lines. An appropriate year-round tilt for your PV array should equal your latitude. Mine, in Bear, Delaware, is 39.3°.

Kevin McMullin • Bear, Delaware

SOLAR MYTH

It has become obvious to me that certain young and fast-growing industries use their influence in ways that may not serve the public best. They rapidly move to slogans and myths about their importance and serviceability to the markets and customers they seek. More and more, I have seen a distortion that is making its way to the broader media coverage in the form of one of the most prevalent myths, and one that certain industries enjoy and promote. That is the myth that solar energy is (only) electricity.

The fact is that solar energy converted to heat is a far more efficient process than solar electricity and can be stored for later use. It is measurable as watt-hours, just as electrical energy is, and replaces the equivalent of energy provided with fossil-fuel burning or electricity. Solar heating is also distributed energy production. That means that we can all get our own without buying it from a utility. The energy is free! It is therefore true that nearly any solar electrical energy produced for heating is money wasted, because that money spent for direct solar heating is far more productive, and would direct the solar electric energy for other useful purposes.

According to the U.S. Department of Energy, more than half of domestic and industrial energy use is for heating purposes, coming from electric and fossil fueled sources, yet the solar heating

Courtesy Phil Manke

industry has no dedicated lobbying or PAC fund to feed the suck of funds our corrupt political machine demands. Even the American Solar Energy Society, a wonderful organization for its advocacy of the solar field in general, devotes more articles to PV and concentrated (utility) thermal developments than to distributed solar thermal. I call on them and all other solar publications to do more in the way of education and showing how the United States and others could advance the economic rewards of the renewable and sustainable culture through distributed solar thermal.

Much of proposed grid buildup and fuel burning might be unnecessary if more of the energy could be more economically collected through self-obtained solar thermal means. The most efficient way to turn down the global CO^2 level and thermostat is through the use of sunshine for energy—and heating (and cooling) needs is the biggest part of that. That is no myth.

Phil Manke • Wautoma, Wisconsin

PV PERMIT FEES

I joined the solar electricity industry in 2003 and realized early on that high permit fees are a barrier to wider adoption of this wonderful technology. Many cities charge PV system permit fees based on the full valuation the system's cost, rather than basing them on the resources needed for permit approval and inspections. Here in California, it is required under state law that solar permit fees be minimized to encourage more solar-electric systems.

In 2005, as chairman of a global warming committee at my local Sierra Club, I created a campaign to get all cities in my community to adopt reasonable PV system permit fees. Sierra Club volunteers surveyed all cities in several local counties to find out the fee to permit a 3 kW residential PV system. There was a wide discrepancy on what neighboring cities charged. We wrote a report and issued a news release about our findings, ranking cities by fee. Cities with the highest fees were contacted to request their fees be reviewed and lowered.

As a result of our efforts, lots of local newspapers covered our campaign and virtually all cities lowered their PV permit fees over a three-year period. Of the 131 cities in the greater San Francisco Bay area, 71 have significantly lowered their fees! The original 2005 Sierra Club permit fee report recommended a fixed PV permit fee of no more than $300. This enables cost recovery for a city that has expertise processing permits. Most cities gave warm responses to our campaign. They were open to setting affordable permit fees and creating supportive policies. City leaders want good publicity to shine on their cities and typically took prompt action on this issue.

There was a surprisingly large impact from our Northern California PV permit fee campaign, so this year we decided to coordinate a similar campaign in Southern California. Partnering with local Sierra Club chapters, we are having similar results! For instance, Los Angeles County lowered their fees in the summer of 2009 from $1,144 (for a 3 kW PV system) down to a fixed fee of $370 that does not vary with system size or value.

The media coverage we received from local papers helped to shine the light on archaic PV permit fees. This applied additional pressure on the cities to respond to our letters requesting these fees be reviewed and lowered. The press coverage also helped to educate the public about solar electricity systems in our community.

You can read the northern and southern California PV permit fee reports with recommendations at www.lomaprietaglobalwarming.sierraclub.org/solar.php.

Kurt Newick • Kurt@GoSolarNow.com

Solar Permit Fee Changes

Fees that have significantly dropped between 2005 & 2008

City	Reduced Fee	Old Fee
Atherton	$250	$970
Belmont	$0	$1,100
Brisbane	$250	$816
Burlingame	$0	$1,022
Campbell	$225	$687
Cupertino	$300	$1,002
Daly City	$490	$986
Foster City	$0	$983
Gilroy	$300	$769
Half Moon Bay	$291	$335
Hillsborough	$0	$699
Hollister	$224	$780
Los Altos	$474	$869
Los Altos Hills	$0	$340
Los Gatos	$511	$1,287
Menlo Park	$0	$411
Millbrae	$358	$1,180
Milpitas	$271	$680
Monte Sereno	$0	$569
Morgan Hill	$222	$1,188
Redwood City	$261	$385
San Bruno	$117	$1,200
San Carlos	$176	$922
San Juan Bautista	$224	$780
San Mateo (City)	$232	$1,224
San Mateo County	$345	$690
Santa Clara (City)	$0	$384
Santa Clara County	$253	$450
South San Francisco	$300	$825
Sunnyvale	$339	$399
Woodside	$30	$728

Courtesy www.lomaprietaglobalwarming.sierraclub.org

CODE CORRECTION

Code Corner (*HP134*) contained several errors in the diagram and computations. To view the corrected document, go to www.homepower.com/webextras.

TO CONTRIBUTE

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

Have Dam, Need Hydro System

I've been reading and studying many of your articles on microhydro. Most are tapping energy from small streams—I have a dam.

There's roughly 10 to 15 feet of head from the intended intake to just below the dam's discharge culvert to the turbine site, which sits downstream 20 feet or so. Going farther downstream and running another 30 to 40 feet of pipe would probably gain a few more feet of head. The flow varies, and I will start measuring this via a container method next time I'm at the site.

The dam is a rock-and-earth-silt structure in which a large welded metal box sits. The box has a divider down the middle into which aluminum plates are inserted. Water levels behind the dam are controlled by adding or removing plates.

The discharge side of the plates (or back half of this box) then drops about 8 feet into a culvert attached on the back of the box. This site is in northern Michigan, so cold weather is an issue, but the water runs all the time except during severe drought.

What type of microhydro design should I pursue? Should I capture the overflow in a penstock to a turbine past the discharge culvert? Or can potential energy be captured from the dam itself and the turbine located inside the base of the box on the discharge side? Or should I run an AC system right off the discharge culvert itself?

The dam is certified/permitted by the state of Michigan, so I don't think installing a microhydro system would be forbidden. My intent is to have an off-grid battery-based system to supply a small camp. Someday, I would like to live there, and microhydro would be a key ingredient to reaching that goal.

Craig Schultz • via e-mail

Your question about using an existing dam for microhydro is a good one. Before discussing your intake question, I'd like to emphasize the importance of accurately determining head and flow before you proceed too far. In the head range of 10 to 15 feet you describe, it takes a lot of water to develop useful power—and every foot of head counts. The simple formula for calculating power at this scale is:

Net head (ft.) x flow (gpm) ÷ 12 = watts x 24 hrs. = Wh/day

If you plan to power a camp with battery storage and an inverter, you can probably get away with as little as 3,600 Wh each day. Thus, you will need a summer flow of at least 180 gpm at 10 feet of head. If you can fill a 5-gallon pail in 1.6 seconds, you could consider this option—180 gpm is just about the maximum flow you can measure with a 5-gallon container; much more than that and the container fills too quickly to time the flow accurately. Perhaps you could use a barrel or tank, or even something larger, to get a more accurate flow measurement. In your situation, much greater flow can be measured using the aluminum divider plate you describe in your overflow as a knife-edged weir. You can find the method and formulae for this technique with a little research on the Web, or in Dan New's excellent articles in the back issues of *Home Power.*

The existing overflow was designed to handle expected flows and protect your dam. The earthen-and-stone dam you describe is subject to failure if high flows overtop and erode the dam. For that reason, I never recommend using existing overflow pipes to develop microhydro. The danger of disturbing the balance of flow and discharge area is too great.

You are better off putting in another intake for the turbine by penetrating the dam at one end. The penstock should be located about 2 to 3 feet below the water surface. Create the intake with a concrete box facing into the pond, with a screen covering of at least 4 square feet. Place your turbine and generator off to the side of the stream, and as low as possible. Protect it from high flows with a concrete or block enclosure. Wood will work if you can drive wooden pilings to anchor things. Get some good advice on penetrating the dam and be sure to backfill your excavation with rammed clay. If this isn't done correctly, you could jeopardize the dam. Always consult an engineer and contact the state before starting work on a dam.

As an example, let's size your penstock for 200 gpm and 40 feet in length. Using loss tables, a 6-inch PVC pipe will only lose about 2.5 inches of head over 50 feet if it is a straight run. That calculation shows the head loss to be insignificant and that the 6-inch penstock is of sufficient size.

Besides sizing your system to work correctly, you'll need to have a way to shut it down in case of flooding or system maintenance. One way to stop the system is to drop a piece of steel over the pipe inlet at the intake. Be sure to put in a riser pipe from the penstock to above lake level to let air in when you shut down or you may crush the penstock with atmospheric pressure. If you choose to use a valve, use a gate valve so you have to close it slowly, and keep it at least 5 feet upstream (10 pipe-diameters) from the turbine. This lets the water "straighten out" before it gets to the turbine, since turbulence affects power. Good luck, and most of all, have a good time.

Ron MacLeod • Nautilus Water Turbines

"In the head range of 10 to 15 feet you describe, it takes a lot of water to develop useful power."

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The primary causes of positive plate deterioration are positive grid corrosion and positive active material wear-out or softening and shedding. These failure modes are the result of the normal overcharge required to fully charge batteries and to mix the electrolyte to prevent electrolyte stratification. In addition, batteries that are used in applications that require continuous float charging may be more susceptible to grid corrosion as a result of prolonged overcharging. Also, batteries that are subjected to frequent deep discharges (greater than 50% DOD) often exhibit increased effects from positive active material wear-out. This is usually the case in Renewable Energy applications. Testing at U.S.Battery has shown that an effective method for mitigating the effects of positive plate deterioration is to increase the ratio of positive to negative active material by ***adding a positive plate*** and removing a negative plate from a conventional cell design resulting in an Outside Positive (OSP™) cell design vs a conventional Outside Negative (OSN) cell design. This design approach results in a cell with increased positive to negative active material ratio, increased positive to negative grid ratio, and increased protection of the positive plate from positive plate deterioration. This results in longer life, increased capacity, and more stable performance over the life of the battery.

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Electrical shorting can be caused by 'mossing' shorts at the top of the cell element. These mossing shorts are the result of positive active material particles that have softened and shed from the positive plates, become suspended in the electrolyte, and eventually collect at the top of the cell element. Once enough of this material has collected to bridge the tops of the separators, it can contact both a positive and a negative plate where it converts to conductive lead and forms a short circuit resulting in cell and battery failure. This failure mode is more prevalent in stationary applications than in vehicular applications because of the absence of vibration and shock that normally dislodges the mossing material and causes it to fall to the bottom of the container where it collects innocuously in the mud cells. Testing at US Battery has shown that the use of insulating 'moss shields' in batteries used in these stationary applications can effectively prevent the formation of these mossing shorts. This results in longer life, increased capacity, and more stable performance over the life of the battery.

SPECIFICATIONS
RE L16 / 6-VOLT

AMP HOURS (100hr.rate)	470
AMP HOURS (20hr.rate)	428
AMP HOURS (5hr.rate)	334
MINUTES (@ 75 AMPS)	254
MINUTES (@ 25 AMPS)	914
LENGTH	11-7/8" (302mm)
WIDTH	7-1/8" (181mm)
HEIGHT	16-3/4" (425mm)

U.S.Battery Manufacturing Company

SEPA solar electric power association

RE SERIES

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Phantom Fighter

I am building an off-grid home in northern California. Our electricity will be supplied by PV modules, batteries, and a backup generator. I want to reduce phantom and other wasteful loads as much as possible. Most information about reduction advises users to positively switch off any loads not in use. Nothing much is advised where switching is not an option (smoke detectors) or is otherwise undesirable (video recorders and security devices).

In an on-grid situation, an "always-on" 110 VAC load of "X" watts consumes "X" watts times 24 hours. But the situation is different in an off-grid situation, where the same "X"-watt load consumes "X" watts times 24 hours, *plus* the number of watt-hours consumed by the inverter. If that inverter is the whole-house inverter, then my understanding is that a small load can trigger significant energy consumption. This suggests that an energy-saving strategy for small, "always-on" loads would be to power them with a separate small inverter, sized and dedicated for this use.

Are there any problems (practical, code compliance, or otherwise) with using a small, dedicated "always-on" inverter? Can you suggest criteria for selecting reliable small inverters for long-term, constant use?

Alan & Rhoda Slagle • Fair Oaks, California

While this is not a simple question, here are some things for you to consider. It is true that inverters take some amount of "idle wattage" or "overhead" just to stay on, and that they are less efficient when run at low capacity. But the energy consumed with small loads is not necessarily the load plus the overhead, because some of the overhead is apportioned to *each* load that is on during the day, not just the small load in question. So the overhead for that small load might be a little less than you think. You need to examine a particular whole-house inverter's specs to see what the overhead is. If it is not much, then you might be better off adding to your PV array to deal with the losses, rather than complicating your system with a second inverter.

The concept of a second, small, always-on inverter is interesting. But keep in mind that there is also overhead there, and your total savings will not be equivalent to the savings from the whole-house inverter being off, but rather the whole-house inverter's savings minus the small inverter's overhead. That decreases the value of this idea a little more. However, if you choose that strategy, select the smallest pure sine-wave inverter you can.

If code compliance is a factor, make sure your small inverter is UL-listed and that it is wired into the dedicated AC circuits it will be powering, through its own mains box and breakers. It will also require its own battery-to-inverter cabling and DC disconnect. And everything will have to be wired to code. All of these requirements can add significant expense to the overall system cost—again, making attractive the idea of adding extra PV power instead of an inverter.

Instead of AC-powered smoke detectors, consider the simple 9-volt battery-powered ones or DC-powered ones that can be hard-wired. They come in various voltages, though 12 V ones can be hard to find. For DC circuits, use a high-efficiency converter for getting 12 V from your battery voltage. This will mean further wiring, and a DC distribution box with DC breakers. Check out one brand of converters at www.solarconverters.com.

But you'll need to consider if going through all this effort is worth it. Most off-gridders think it's not—too much added effort, trouble, and equipment, and much more to go wrong.

Michael Welch • *Home Power* Senior Editor

"...you might be better off adding to your PV array to deal with the losses, rather than complicating your system..."

Heat Pump Sizing

I am trying to size a heat pump for our 2,550-square-foot home in north-central Florida. I have the detailed winter and summer load data; sensible, latent loads; etc. How do I take that data and determine what size of unit is appropriate? I am looking for a detailed process. Be aware that in this location, the unit needs to be slightly undersized so that it will run longer to help remove our high year-round humidity levels, which are made worse by a tightly sealed home.

Lane Watkins • Lake City, Florida


Courtesy www.bbwassociates.com

In your area of the country, the summer (cooling) load is used to determine the size of the heat pump. You mentioned the two components of the building's cooling "load" (or heat-gain calculation, in British thermal units—Btu). The sensible load is the energy required to change the temperature you can feel, and the latent load is the energy required to remove the moisture in the air.

Too often, heat pumps are sized using a "rule" method that equates square footage of living area per ton of capacity. In the South, systems are often sized using "the rule" of 600 square feet of living area for each ton of capacity. This is asking for trouble, because, in a well-built and insulated house, the heat pump might be oversized, and not run long enough to remove the latent moisture in the home, resulting in mold and mildew growth. Instead, calculations should be based on the fact that there are 12,000 Btu in one "ton" of air-conditioning. For instance, if the total sensible and latent loads equal 36,000 Btu, a 3-ton heat pump will be needed.

In humid central Florida, it would be wise to consider a two-speed heat pump, which runs longer and removes more moisture from the air. Also, if the building is indeed tightly sealed, you may consider an energy recovery ventilator, which introduces a constant flow of fresh air to the home, while exchanging heat energy between the incoming and outgoing air.

If you do a Web search for "manual J load calculation software," you'll find there are many programs available to size heat pumps, furnaces, and air conditioners. They range in price from about $300 to thousands of dollars. Any good mechanical contractor should have access to this software. If you can't find help locally, try the Florida Solar Energy Center at www.fsec.ucf.edu. They will have a list of home energy raters who can size heat pumps.

Charles Davis,
The Earth Comfort Company •
Savannah, Georgia

Solar Cars

If light, efficient electric vehicles (EVs) were manufactured, could it be become feasible to use a solar-electric array to charge the batteries for an average driving range of 40 miles each day? How big of a system would be needed, and how much would it cost?

John Lewis • Boise, Idaho

First, a typical crystalline PV module is rated at about 10 to 14 watts per square foot, so you'll need a lot of modules to keep your batteries charged—too many to mount on the car. But it's definitely feasible to use a PV array at your house to recharge your EV's batteries. Ideally, use a grid-tied system with time-of-use metering to allow off-peak car charging, while taking advantage of on-peak PV production.

Two EV classes that are great candidates for PV charging are the neighborhood EV (NEV) and the compact EV. The NEV is limited to 25 to 35 mph, while the compact EV can drive at highway speeds.

With gasoline cars, we look at economy in terms of miles per gallon (mpg). With electric cars, we use kilowatt-hours per mile (kWh/mile). "Mileage" reports range from 0.11 to 0.32 kWh per mile with EVs like the Toyota RAV4-EV and the TEVan (an EV built on a Chrysler minivan body). This means that these highway vehicles can travel between 3 and 9 miles on 1 kWh of electricity and the small NEVs can do even better.

If you drive 40 miles per day, you can expect to use 4.4 to 12.8 kWh. In Boise, with an average of 5.2 daily sun-hours, a 1.2 to 3.4 kW PV system will be needed to offset the energy consumed by the electric car. The cost of the system will be $10,200 to $28,900 (figuring $8.50 per watt for an installed system). Calculations were made using Boise, Idaho, insolation data and PVWatts software, using the default derate and assuming ideal array orientation and tilt, and no shading.

If that sounds expensive, consider this: Many utilities' time-of-use billing programs, which offer cheaper electricity rates at night and sync well with when you'll be recharging

Courtesy Kevin Johnson & Lisa Brown

Kevin Johnson and Lisa Brown charge their EV with sunshine, courtesy of their 3 kW grid-tied PV system (see *HP117*).

your EV's batteries. A utility, for example, may charge 6.5 cents per kWh between the hours of midnight and 7 a.m. instead of the 13 cents per kWh standard retail rate. So you can charge at night, and pay cheaper rates, and when you're driving your EV during the day, the PV system will be cranking out electricity, which, under net-metering agreements, will be credited at the higher daytime TOU retail rate.

"Two EV classes that are great candidates for PV charging are the neighborhood EV (NEV) and the compact EV."

Using the TOU example above, an EV owner could use a much smaller PV system to pay for their EV charging. Using the same 40 miles per day, a 0.6 to 1.7 kW system would provide enough credit to cover the EV charging, at a cost between $5,100 and $14,450. This scheme is being used by several EV owners to offset all their transportation fuel needs.

Another issue not to be ignored is the amount of carbon that is produced when using the grid as a vehicle's energy source. It's a given that when a standard vehicle is burning fuel in its engine, it releases carbon into the atmosphere. What is not so obvious is that grid-charged electric vehicles also release carbon—unless the electricity is produced by a renewable energy source. According to the U.S. Energy Information Administration, 48.5% of the electricity generated in the United States is produced from coal. Per coal-fired kWh used, 1.37 pounds of CO_2 are released. This means that electric cars are not the final solution to reducing our carbon footprint—unless we power them with renewably produced energy. So if you use the TOU method to offset the electricity your electric car uses, it won't offset all the carbon released.

Kelly Larson • NABCEP-certified PV installer, California Electrical Contractor

Solar Hot Water Sizing

Is there a user-friendly spreadsheet or online sizing tool available for sizing a solar hot water system?

Marc Fontana • via e-mail

The Department of Energy sizing guideline of 1 square foot of collector to every 1.5 gallons of storage works well in most of the country except for the desert Southwest, where sizing should be closer to 1 square foot of collector to every 2 gallons of storage. The DOE's guide for solar hot water systems can be downloaded at http://www.nrel.gov/docs/fy04osti/34279.pdf. For more accuracy, use the method Carl Bickford describes in his article in *HP118*.

A shortened version of Carl's method uses data for collector output from the Solar Rating Certification Corp. (SRCC) site and 30-year averaged climate data from the "Redbook" at http://rredc.nrel.gov/solar/pubs/redbook. Assuming you know the hot water requirements, use the Redbook to look up your local solar radiation for the tilt that most closely matches your proposed installation.

The Redbook gives solar irradiance in kWh/m^2 per day, which needs to be converted to Btu/ft.^{2} per day to use the SRCC data. Multiply the average for your location at the installation tilt angle by 317.1 to arrive at an average Btu/ft.^{2} per day average. (Most will be between 1,000 and 2,000 Btu/ft.^{2}/day.) Use this solar radiation to categorize the climate for the specific collector you are using in the OG-100 catalog. Each collector will have one page of data in the catalog. The matrix table listed on the individual collector's page is used to estimate collector output. Use the "C" category (water heating) in the matrix and the climate category from the Redbook calculations to determine the collector's estimated output. A "Clear Day" has 2,000 Btu/ft.^{2}; a "Mildly Cloudy" day has 1,500 Btu/ft.^{2}; and a "Cloudy Day" has 1,000 Btu/ft.^{2} The rest is an estimate of system performance. Use 70% if the system has a heat exchanger and 80% if it is direct circulation.

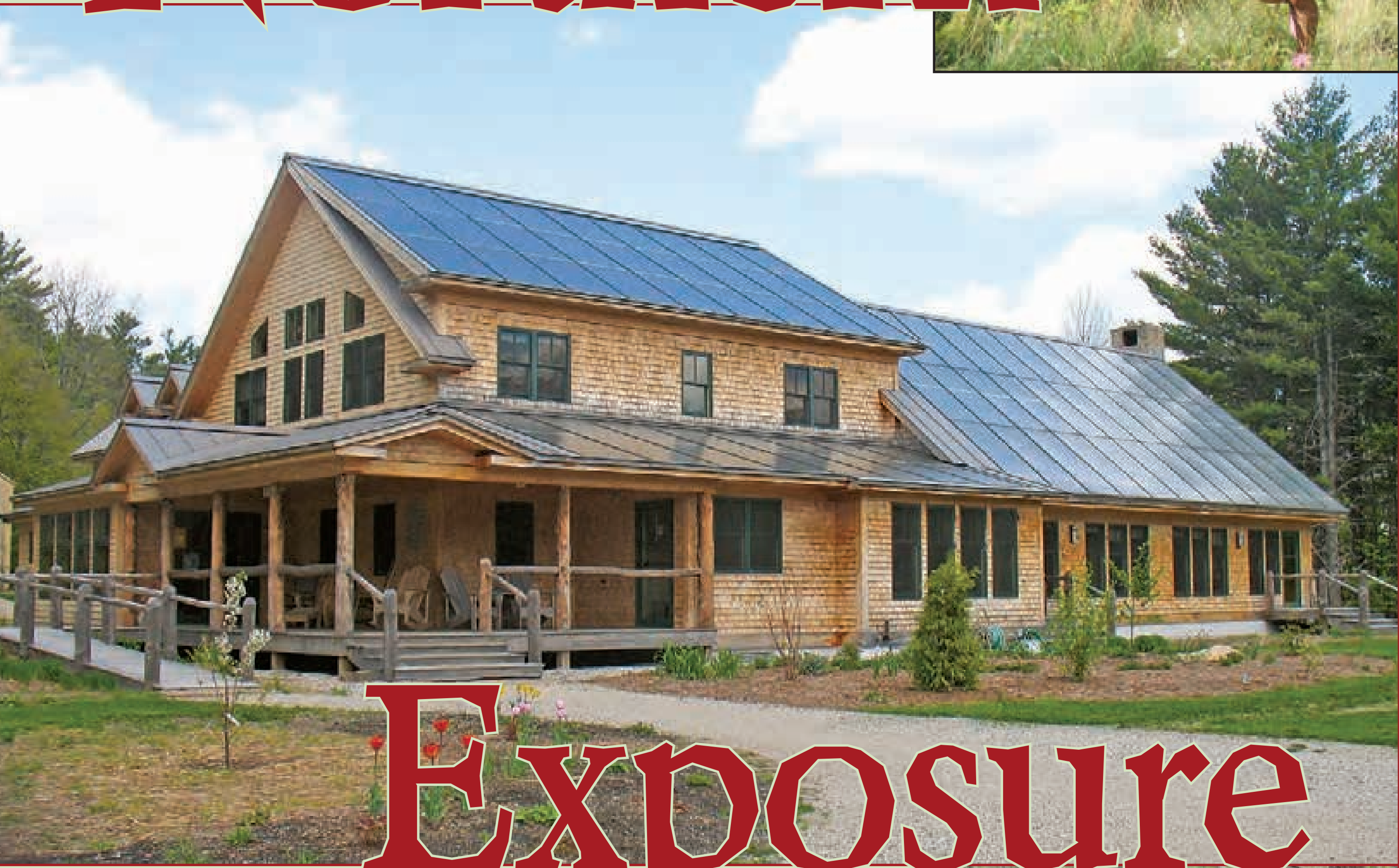
If the system being installed has an SRCC OG-300 certification, the estimate is simple. The SRCC publishes the OG -300 results in a condensed format for more than 100 cities in the United States. Find your location or the closest city and look up the system by the OG-300 number. The city data will give the estimated output of certified systems in kWh or therms displaced depending on the fuel use. (There are 3,412 Btu/hr. in a kW; 100,000 Btu equals 1 therm.) The OG-300 catalogs for cities can be downloaded from the SRCC Web site at www.solar-rating.org.

Chuck Marken • *Home Power* Thermal Editor

To submit a question to
Home Power's **Ask the Experts,**
write to: **asktheexperts@homepower.com**

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

Northern Exposure



by Kelly Davidson

A New Hampshire environmental center proves that solar technologies aren't just for low latitudes and sun-kissed climes.

Top to bottom: Courtesy Donna Dolan (2), Chris Denuzzio, Donna Dolan, Tom Eastman

For the naturalists at Tin Mountain Conservation Center, getting close to the earth is more than a job requirement—it's a way of life. Whether leading school bird-watching trips, sifting through swamp muck with young summer campers, or developing forest management plans as part of an intensive ecology course, the TMCC staff has always been more at home in the outdoors than in an office.

Founded in 1980, the nonprofit advocates environmental preservation through earth science education and outdoor activities. The organization hosts an array of educational programs and summer camps in schools and communities throughout northern New Hampshire and parts of Maine. After years of renting office spaces and even running programs from the trunks of staff members' cars, the organization is finally settling into a proper home—an 8,500-square-foot facility in Albany, New Hampshire, designed to reflect the TMCC's environmental mission and fully use the few sun-hours the site receives.

Set on a 138-acre sanctuary acquired through donations and in conjunction with a local land trust, TMCC's new Nature Learning Center was completed in August 2006. Twenty different locally harvested woods were used for the framing and finishes. But a major feat is that this northern New Hampshire building meets nearly all of its energy needs with solar energy produced on the roof.

The $1.9 million facility provides a long-overdue home for the organization's administrative offices, as well as a classroom lab, library, great room, small kitchen, and two conference rooms. The new center is a hub of activity, with as many as 300 people passing through during any given week for various field trips, lectures, and events.

Taking the Solar Challenge

It took more than a decade of planning to bring the project to fruition. The architecture firm of Christopher P. Williams of Meredith, New Hampshire, led the design effort, working with TMCC to realize its vision. Initially, the budget dictated passive solar options, but partway through the design, one of the project backers advocated a more active approach—and offered to pay for solar-electric and solar hot water systems.

The high latitude (43.96º N) and tree-filled site posed big challenges. In many portions of northern New Hampshire, the sun is only visible above the tree line for about three hours per day for much of the year—that is, *when* it shines. And this site's winter solar window—from 10:30 a.m. to 1:00 p.m.—left little room for design error.

Determined that it could be done, the backer/donor sought out Steven Strong of Solar Design Associates, a renewable-energy design firm based in Harvard, Massachusetts. While other installers and engineers shied away, saying that there was not enough sunshine at the site to produce adequate solar energy, Strong saw the potential and signed onto the project as a design consultant for the mechanical and solar systems. He was confident not only that solar energy would work for the facility, but that it would meet most of its energy needs. His strategy: obsessive and aggressive efficiency.

The Tin Mountain Conservation Center provides environmental activities and education for all ages.

Top to bottom: Courtesy Donna Dolan, Katelyn Dolan (2), Donna Dolan

The center used sustainably harvested wood from local species throughout the rooms, making the structure an educational lesson in itself.

John Hession (4)

"We set an energy target of net zero, and collaboration with the architect was key to meeting that goal. The architect must be on the same wavelength as the solar system designer. If they aren't, then you can't get there," Strong says. "We were fortunate to work with an architect who fully understood the importance of elevating energy efficiency to the top of the priority list and that every single decision—from concept to construction—needed to be made with energy consumption and solar in mind."

TMCC's only request was that the systems not detract too much from the site's natural beauty. Having already chosen locally grown white cedar for the exterior siding so that the building would blend with the wooded site and complement the nearby barn, TMCC staff hoped that the systems could be integrated in a way that demonstrated both the functionality and beauty of solar energy.

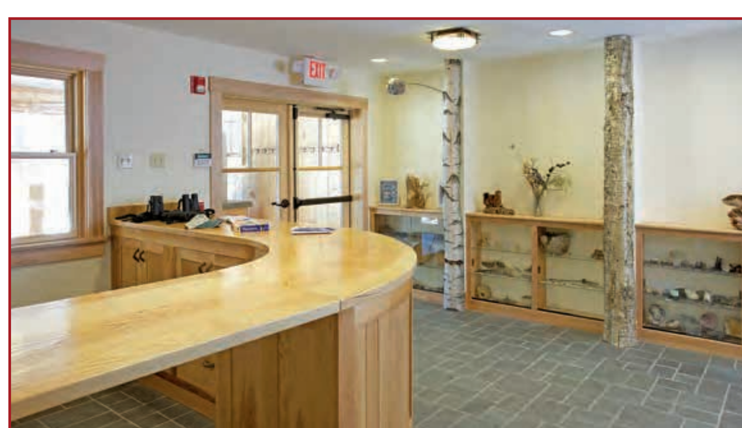
Shaping the Solar Cone

The Nature Learning Center's land—a farm turned second-growth forest—is one of three sanctuaries managed by TMCC and utilized for its nature programs. To preserve the historic orchards on the farm and minimize the intrusiveness of parking areas and driveways, the building was located near the road and an existing nineteenth-century barn, which was rehabilitated and now serves as a storage facility.

An area that had been previously logged was chosen as the site for the "solar cone"—the portion of the property where solar access was needed and would be improved by removing trees. This limited cutting to the smaller of the second-growth trees on the property. Small trees were sawed into firewood, while the larger ones were milled into sheathing and finish materials for the building. Opening up this solar cone allows the site to capture available sunlight for about 2.5 hours per day during the winter.

Strong suggested that both systems be integrated into the roof—essentially becoming the roof—rather than using the traditional approach of mounting the solar systems on top of the roof. Applying the same techniques used in commercial glazing applications for skyscrapers and storefronts, the custom "sloped glazing" design utilizes the PV modules and solar hot water collectors as the weatherproof barrier.

TMCC staff and board had a small case of sticker shock when they learned that the design and installation of such specialized systems would cost close to $300,000, but with the donor willing to pay a premium to make it happen, there was nothing holding them back. While the cost for an integrated system was significantly higher than traditional roof-mounted systems, Strong convinced TMCC that the integration would pay off in the end—both aesthetically and financially.



"A roof made from PV and solar thermal collectors will last longer than most conventional asphalt-shingle roofs," Strong says. "So, while an integrated approach is more expensive up front, it all probably works out in the end when you consider the cost of repairing and replacing an asphalt roof—and having to pay someone to remove and dismantle your system to do those repairs."

Efficient Design

The new solar plan required considerable changes to the original building concept. Williams returned to the drawing board, changing the angles and dimensions of the roofs to better accommodate the PV and solar thermal arrays. Among other efficiency upgrades and mechanical modifications, vents and air space also had to be added in the eaves to allow excess heat to escape. Fortunately, the original design already included a basement, which easily accommodated the mechanical and electrical for both systems and the backup boiler.

Large areas of south-facing roof accommodate the solar thermal and PV systems. On the south roof of the great room, sloped at 40°, flat-plate collectors with low-iron tempered glass make up the 1,200-square-foot solar thermal array that feeds the radiant floor heating and the 1,500-gallon storage tank in the basement.

Forty-three 300 W Schott modules are wired in seven subarrays and integrated into adjacent roofs. The upper story roof's five subarrays slope at 30°, while the porch roof with two subarrays slopes at 12°.

Key to TMCC's "near net-zero" electricity footprint are New Hampshire's fairly progressive net metering rules. All utilities are required to offer net metering, and unlike many states, net excess generation is carried over to the next billing period indefinitely—meaning that any summer surplus can be used in the darkest days of winter, until all the credit is used up.

It is because of this carryover that the gentle roof angles, which help to maximize summer production, make solar work well for this building. "With New Hampshire's indefinite carryover, it's actually a disincentive to angle the roof for winter harvest, and it's best to maximize production during the sunniest times of the year—late spring, summer, and early fall," Strong says. "You have to make hay while the sun shines. Here, it doesn't much matter when you produce solar energy just so long as you do."

Alternatively, he had hoped for a steeper roof angle for the solar thermal array, which would optimize production during the winter months when the sun is low in the sky and demand for hot water is highest. Mounting the collectors at latitude plus 15° (tilted about 60°) might have produced about 4% more energy in winter (October to March). Summer production would have diminished slightly but not enough to affect the load coverage. But only so much could be done with the layout and geometry of the structure since each roof section had to fit with the style of the building.

Other Efficiencies

In place of traditional oil or electric space heating, a radiant floor heating system was chosen, along with two heat

Carry In, Carry Out

Instead of hiring a general contractor to oversee the construction, TMCC acted as the general manager, assembling a local crew and handling all the subcontracts.

"We wanted to have more control over how the facility was built and ensure that it was done in a way that reflects our principles. Everyone on the crew came on as much for the job as for the opportunity to help support us and our mission," says Michael Cline, TMCC's executive director.

While most were highly respected tradespeople in the area, many had never worked on a green building project. For example, the construction manager was a boat builder by trade but had the right philosophy and the skills TMCC needed to coordinate the effort.

"I had my reservations at first, but it was a phenomenal group of people, and everyone really respected Tin Mountain's mission in a way that another crew might not have," says Christopher Williams, the project's architect.

"A perfect example is the way waste was dealt with. The motto on the job was 'carry in, carry out'—just like the backpacking principle. Anyone who created trash had to deal with it, and they did," says Williams. "That's a mind-set you don't normally see on a typical construction site."

One of the few exceptions to the local crew was the solar systems installer. Given the complexity of the roof-integrated design, TMCC brought in KW Management Inc., an installation company in Nashua, New Hampshire, that had worked with Solar Design Associates on other custom installations and was familiar with its proprietary roof-integrated assemblies.

A local electrician and plumber also helped with the month-long installation, because TMCC wanted to have technicians in the area who understood the systems and could respond to urgent repair calls.

Courtesy Donna Dolan

The roof-integrated PV arrays provide form and function—a roof structure and power-generating station—all in one.

Sizing for Near Zero-Energy in the Northeast

The grid-tied 12.9 kW solar-electric system was predicted to provide 91% of the facility's electrical needs, based on a comprehensive load analysis performed by Solar Design Associates. Accounting for day-to-day demands was fairly straightforward—eight staff members working five, eight-hour days per week and running at least four computers, various lights, and other appliances at any given time. Operational loads were fairly predictable as well—exterior porch lights, parking lot lights, an Energy Star refrigerator, a dishwasher, and a washer and dryer.

It was the unpredictable higher-than-normal demand for special events, meetings, and various classes that complicated the system sizing. While the annual electrical load was estimated to be 15,457 kWh and the PV system was estimated to generate 14,127 kWh per year, it turns out that these estimates were slightly conservative. In its first year of production, the PV system actually generated 19,000 kWh, while the building consumed 18,000 kWh, showing the potential for a slight surplus of energy for some years.

PV System Tech Specs

Overview

System type: Batteryless, grid-tied solar-electric

Location: Albany, New Hampshire

Solar resource: 4.6 average daily peak sun-hours

Record low temperature: -29°F

Highest average high temperature: 80°F

Average monthly production: 1,217 AC kWh

Utility electricity offset annually: 105% for first year

Photovoltaic System Components

Modules: 43 Schott, 300 W STC, 50.6 Vmp, 5.9 A Imp, 63.2 Voc, 6.5 A Isc

Array: Seven subarrays—three five-module series strings; two six-module series strings; and two eight-module series strings, 12.9 kW DC STC total

Array combiner box: Square D with 10 A breakers

Array installation: Solar Design Associates' mounts installed on south-facing roofs, 30° tilt and 12° tilt

Inverters: Two SMA America Sunny Boy, 3,800 W rated output, 500 VDC maximum input, 200–400 VDC MPPT operating range, 240 VAC output; two SMA America Sunny Boy, 2,500 W rated output, 600 VDC maximum input, 250–550 VDC MPPT operating range, 240 VAC output

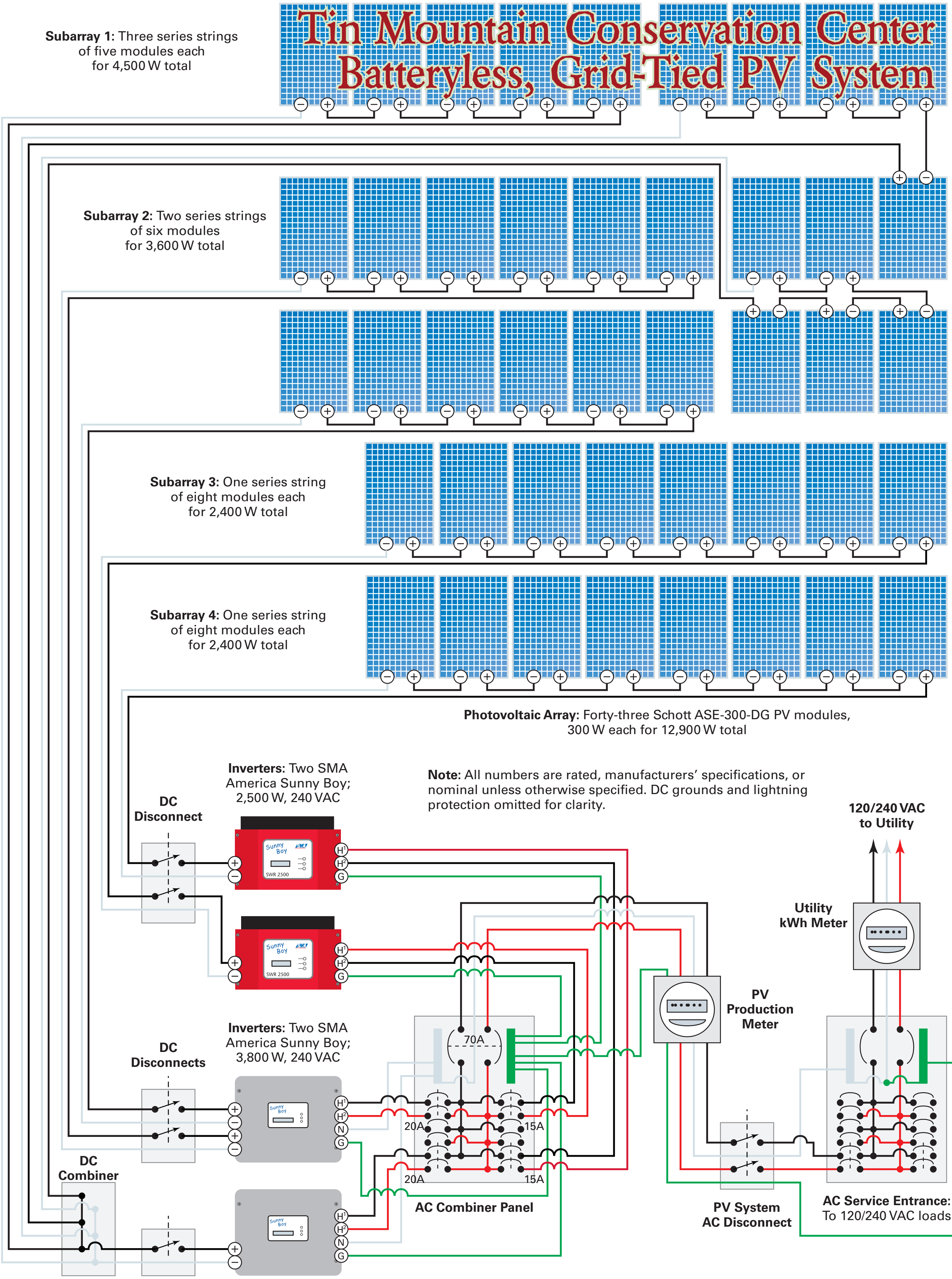
System performance metering: Sunny Boy Control

recovery exchangers and a high-efficiency multifuel boiler for backup. Individual zone controls allow for greater heating control throughout the building. One of the challenges with solar heating in this region is that when the heat is needed most, it is often cloudy—so backup heating is crucial. Finally, a wood-burning fireplace helps heat the nearly 1,500-square-foot great room.

Passive solar design elements were also incorporated. Large south-facing windows help passive gains, while smaller windows on the north side help reduce heat loss. Aligning primary activity areas—great room, library, and some offices—along the east-west axis allows those rooms

Four SMA America Sunny Boy inverters handle the various voltage operating ranges from the PV subarrays.

Courtesy Michael Cline


Tin Mountain Conservation Center
Batteryless, Grid-Tied PV System
Subarray 1: Three series strings of five modules each for 4,500 W total
Subarray 2: Two series strings of six modules for 3,600 W total
Subarray 3: One series string of eight modules each for 2,400 W total
Subarray 4: One series string of eight modules each for 2,400 W total
Photovoltaic Array: Forty-three Schott ASE-300-DG PV modules, 300 W each for 12,900 W total
Inverters: Two SMA America Sunny Boy; 2,500 W, 240 VAC
Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified. DC grounds and lightning protection omitted for clarity.
120/240 VAC to Utility
DC Disconnect
Utility kWh Meter
PV Production Meter
Inverters: Two SMA America Sunny Boy; 3,800 W, 240 VAC
DC Disconnects
70A
20A
15A
20A
15A
DC Combiner
AC Combiner Panel
PV System AC Disconnect
AC Service Entrance: To 120/240 VAC loads

to gain passive heat in the winter. Overhangs shade southern glass from the summer sun, and window positions allow for cooling cross-ventilation in most spaces.

The real key to the "net zero" design is the thermal integrity of the building envelope. Spray-in polyurethane foam and blown-in fiberglass insulation are used in the wall and roof cavities throughout the building—except in the great room, where timber-frame construction supports 6-inch-thick structural insulated panels that have an R-38 insulation value.

At the foundation, layers of fiberglass and foam insulation keep frost at bay. Custom-built doors made from local hardwood and double-pane argon-filled windows prevent drafts. The great room's fireplace—built of stone from the site's abandoned quarry—includes an exterior thermal break, as well as throat and chimney-top dampers to minimize heat loss.

Courtesy Donna Dolan

Custom-made solar thermal collectors fabricated by SunEarth serve as the roofing for the main conference room and provide hot water for the building.

Nothing But Net

Despite a few glitches along the way, mainly linked to the installation of the boiler and an undersized circulating pump for the tank, both the solar-electric and solar thermal systems are working flawlessly, says Michael Cline, TMCC's executive director.

Now in its third year of occupancy, TMCC is meeting nearly all of its energy needs with solar energy produced

SHW System Tech Specs

Overview

System type: Drainback solar hot water

Location: Albany, New Hampshire

Solar resource: 4.6 average daily peak sun-hours

Ave. daily production: 500,000 Btu/day

Percentage of hot water produced annually: 75%

Equipment

Collectors: 12, Sun Earth Inc., 4 ft. by 22 ft. each

Collector installation: South-facing roof, 45° slope

Heat-transfer fluid: Water

Circulation pump: Two primary, two booster; Taco 007

Pump controller: Tekmar 155

Storage

Tanks: STSS, Opes 1, 1,550 gal.

Heat exchanger: STSS, 180 ft. of 3/4-in. copper pipe

Backup DHW: Superstor, SSU, 60 gal.

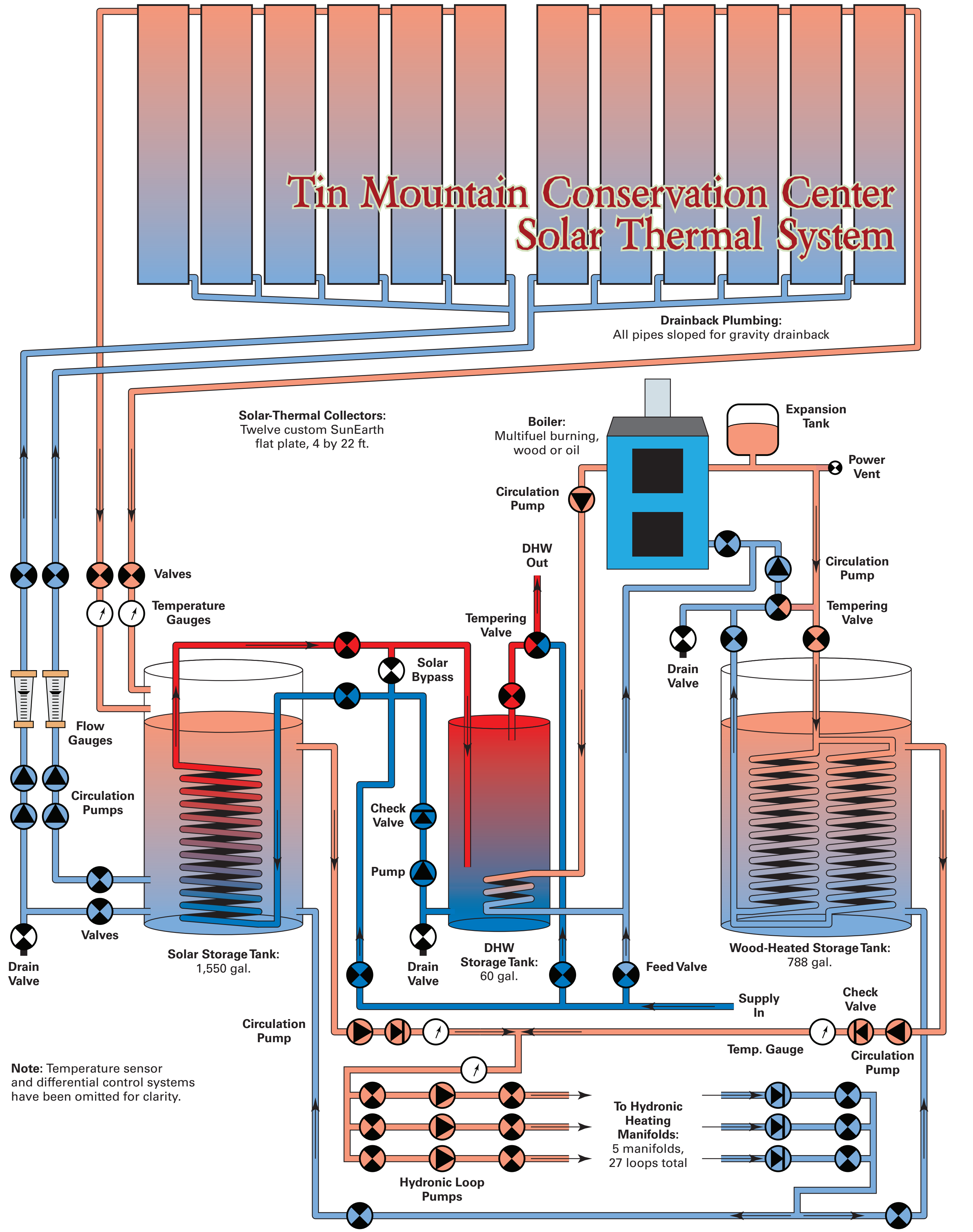
System Performance Metering

Thermometer: DS-60, Azel

Flow meter: F-451004LHN-24, Blue White, sight-glass/flow

The hydronic in-floor heating is powered by solar collectors, with a wood-fueled boiler for backup.

Courtesy Michael Cline


Tin Mountain Conservation Center
Solar Thermal System
Drainback Plumbing:
All pipes sloped for gravity drainback
Solar-Thermal Collectors:
Twelve custom SunEarth
flat plate, 4 by 22 ft.
Boiler:
Multifuel burning,
wood or oil
Expansion
Tank
Power
Vent
Circulation
Pump
DHW
Out
Circulation
Pump
Tempering
Valve
Valves
Temperature
Gauges
Tempering
Valve
Solar
Bypass
Drain
Valve
Flow
Gauges
Circulation
Pumps
Check
Valve
Pump
Valves
Drain
Valve
Solar Storage Tank:
1,550 gal.
Drain
Valve
DHW
Storage Tank:
60 gal.
Feed Valve
Wood-Heated Storage Tank:
788 gal.
Supply
In
Check
Valve
Circulation
Pump
Temp. Gauge
Circulation
Pump
Note: Temperature sensor
and differential control systems
have been omitted for clarity.
To Hydronic
Heating
Manifolds:
5 manifolds,
27 loops total
Hydronic Loop
Pumps

John Hession

Oil has never been used in the multifuel furnace that serves as backup for the solar thermal system.

on site. In 2008, the PV system generated 13,500 kWh of electricity. The total used by the building was 14,000 kWh, resulting in an shortfall of 500 kWh purchased from the local utility (Public Service of New Hampshire).

Meanwhile, the solar thermal system continues to provide about 75% of the space heating and domestic water heating needs, with the remaining heat provided by second-growth wood cut from the property—about four cords annually used for the boiler backup system. Perhaps best of all, no fuel oil has been used in two years.

Access

Home Power Associate Editor **Kelly Davidson** (kelly.davidson@homepower.com) recently conducted a do-it-yourself energy audit on her apartment in Takoma Park, Maryland. As a renter, she cannot replace the old doors and windows, but she's doing what she can to seal air leaks and reduce phantom loads.

Tin Mountain Conservation Center • www.tinmtn.org

Christopher P. Williams Architects • www.cpwarchitects.com • Building design

KW Management Inc. • www.kwmanagement.com • Installation

Solar Design Associates • www.solardesign.com • PV & solar thermal system design

PV & SHW System Major Components:

Schott • www.schottsolar.com • PV modules

SMA America • www.sma-america.com • Inverters

SunEarth • www.sunearthinc.com • SHW collectors

Taco • www.taco-hvac.com • Circulator pumps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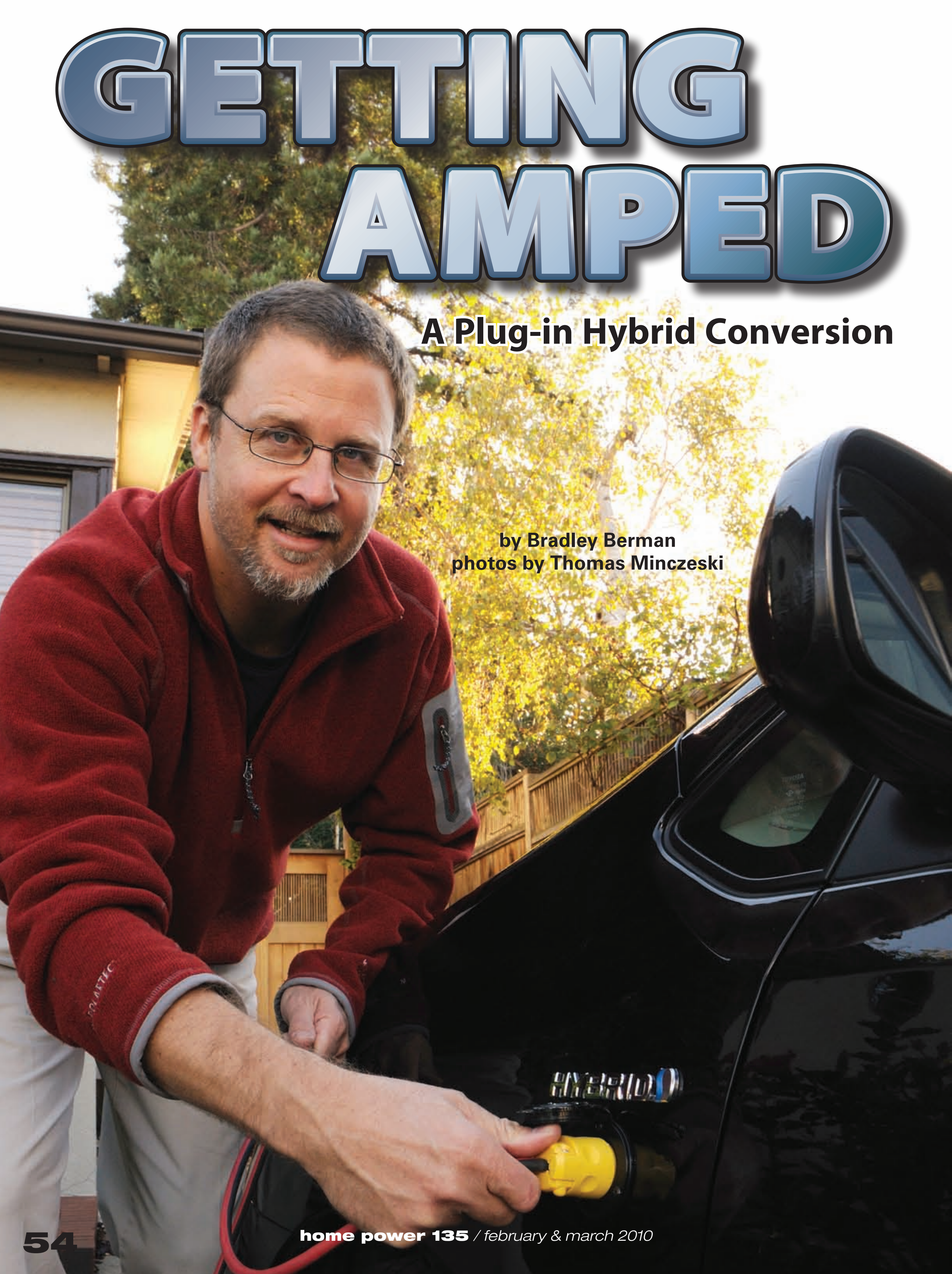
GETTING AMPED

A Plug-in Hybrid Conversion

by Bradley Berman
photos by Thomas Minczeski



The drizzle turned to a downpour when I pulled my Prius into the funky Berkeley, California warehouse serving as the digs for 3Prong Power, a startup company that converts conventional hybrid-electric vehicles into cars that can charge their larger batteries at home with 120 VAC. Within minutes, Paul Guzyk and Daniel Sherwood, the founders of 3Prong, had stripped the Prius's hatchback to its core, revealing the stock 1.4 kWh nickel metal hydride battery (NiMH), usually hidden from view behind the rear seats. Seconds later, they had removed the rear seat backs and several plastic panels, clearing a spot where the spare tire usually sits, for an auxiliary 2 kWh lithium-ion (Li-ion) pack. The ensuing several hours of clearing, wiring, and fabricating were to turn my Prius into a high-mpg, *plug-in* hybrid. The goal was to cut my annual gasoline consumption in half, by increasing the battery capacity and adding a switch to drive in all-electric mode for shorter trips, the most common use for vehicles.

Heading to Hybrids

The plug-in hybrid movement has come a long way in 10 years. When I bought my first hybrid, a 2003 Honda Civic hybrid, it was a technological breakthrough. I was amazed that it got about 45 mpg in mixed city/highway driving. But back then, hybrids were a curiosity. Fast-forward to 2010, less than a decade later: the ability for a gas-powered car to juggle energy between an internal combustion engine and a battery-fed electric motor has become a commonplace reality.

The rapid growth of the hybrid market—though still less than 3% of all new car sales—was the smelling salts that global carmakers needed to wake up to the world's environmental and energy realities. There are now more than 1.5 million hybrids on U.S. roads, with more than 20 models available to consumers. And now the auto industry is buzzing with excitement about the next steps: plug-in hybrids and pure electric cars that can greatly reduce or entirely eliminate the use of petroleum.

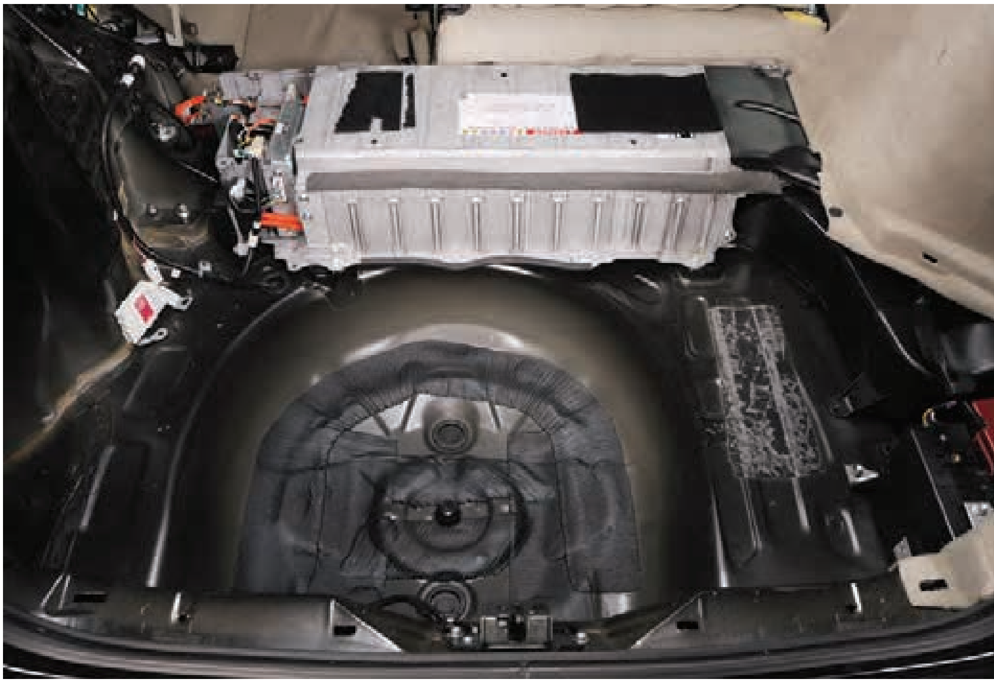
The good news is that auto executives have started to pay more attention to hybrids and electric cars. The bad news is that plug-in hybrids will be considerably more expensive than conventional cars—and they will only begin to trickle out in late 2010. It could be several years before a salesperson can "put you in this car today" and have you silently drive off the lot using "electric" fuel.

Extending the EV Moment

As most hybrid drivers will tell you, the real fun of driving a hybrid car—besides stretching out the time between fill-ups—is the brief periods when the gas engine goes dormant and you're gliding down the road on a magic carpet of battery power. Hybrid engineers have been able to extend those brief "EV moments" in the latest hybrids, especially in the 2010 Ford Fusion Hybrid and 2010 Toyota Prius. But even with those recent improvements, all-electric range usually maxes at a half-mile or so. That leaves folks like me wanting more battery storage—some way to do most of my daily driving on electricity and only occasionally use the gas engine for longer trips or for accelerating and climbing hills.

I have been tracking aftermarket conversion packages and services ever since Felix Kramer, founder of CalCars, hacked his Prius in 2004 and turned it into a plug-in hybrid. Conversion systems, many using the CalCars methodology, have been available for a few years, but they've been pricey—up to $12,000. That's why Detroit-based Enginer's system—$2,500, which includes installation—caught my eye. (Enginer charges $1,000 more to California customers to

Paul Guzyk and Daniel Sherwood, the founders of 3Prong Power, strip the Prius's hatchback to its core, revealing the stock 1.4 kWh NiMH battery, usually hidden from view behind the rear seats.



Technicians prepare the wiring behind the dash for the new "electric vehicle" switch.

help defray costs of the required 5-year warranty.) It's by far the least expensive system I've spotted so far. Could this aftermarket plug-in conversion system mean that plug-in hybrids are ready for prime time? The folks at 3Prong Power asked me to evaluate the system, using my own car as the test platform. I couldn't resist.

My wife Angie and I primarily run a taxi service for our two kids—back and forth from school, music lessons, martial arts, and soccer games, as well as the usual errands to the market, bakery, and bank. (I walk or ride my bike to my office.) Our most common trip is about 10 to 15 minutes, with stops every block or two along the way. A hybrid's gas engine usually takes about 10 minutes to warm up before it will go dormant and allow the electric motor to do more of the work. For our driving, that's just about the time we're pulling back into our driveway, which means we are getting lower fuel mileage than for slightly longer trips.

While the Enginer's 2 kWh battery pack is a pipsqueak compared to the upcoming Chevy Volt's 16 kWh or the all-electric Nissan Leaf's 24 kWh, it might be exactly what we need for our quick trips—a chance to extend those all-electric trips from a few blocks to a couple of miles. A plug-in hybrid offers many of the benefits of a pure electric car without the biggest drawback—limited range. When the batteries drain on a plug-in hybrid, the car reverts back to being *just* a standard hybrid vehicle by running the engine when needed.

Plug-In Particulars

"Electric transportation has zero tailpipe emissions," says Sherwood. "Most studies show that greenhouse gas emissions for electrics are better than for biofuels." Sherwood, an electrical engineer, also installs photovoltaic systems. "You can put solar panels on your house, and you can run your car on sunshine." (See *Ask the Experts* in this issue.)

The Enginer system, developed by auto engineer Jack Chen, is one of about four different flavors of aftermarket plug-in conversion packs on the market (see "Plug-In Hybrid

Plug-In Hybrid Conversion Systems

Manufacturer Web sites list installers near you. All prices include installation, and federal incentives may apply.

Enginer (Detroit, Michigan)

Web: www.enginer.us

2 kWh system: $2,500 ($3,500 in California for state-required certification and a 5-year warranty on PHEVs)

4 kWh system: $3,500 ($4,500 in California)

All-electric range: Approximately 1 mile for the smaller system

Max. speed in all-electric mode: 34 mph

Notes: Expect about a 50% mpg improvement. Not ideal for extended all-electric driving. Can be installed on first-generation Prius with some benefit, but not as much as second- and third-generation models. Kits for DIY conversions are available as low as $2,000.

Hymotion (A123 Systems, Watertown, Massachusetts)

Web: www.hymotion.com

5 kWh system: $10,500

All-electric range: About 15–20 miles (although the Hymotion system blends some gas usage with electricity throughout the driving cycle)

Max. speed in all-electric mode: Not relevant due to hybrid approach

Note: This is the only system that received "provisional certification" from the California Air Resources Board for emissions and is built to meet federal crash-test standards. Testing by national energy labs indicated more than 100-mpg performance.

Plug-in Conversions Corp. (Poway, California)

Web: www.pluginconversions.com

6.5 kWh system: $13,500

All-electric range: 10–15 miles

Max. speed in all-electric mode: 70 mph

Notes: Completely removes factory Prius battery and replaces with larger nickel metal hydride pack. Spoofs the Prius computer. Switch allows driver to turn off internal combustion engine.

Plug-in Supply Inc. (Petaluma, California)

Web: www.pluginsupply.com

5 kWh system: $8,000

10 kWh system: $12,000

All-electric range: 25 miles with 5 kWh system; 50 miles with 10 kWh system

Max. speed in all-electric mode: 52 mph

Notes: Fools the Prius computer with a switch to force shutdown of internal combustion engine.

Connecting the new battery pack to the old increased the capacity by 143%.

Conversion Systems" sidebar). Unlike some other systems, Enginer doesn't hack or "spoof" the Prius computer system and it doesn't remove or replace the existing hybrid batteries.

"We don't even open the hood of the car. We hook into the car's electric system under the dash," said Guzyk. Installers don't cut any factory wiring. The whole system connects to the car with only five wires—three under the dash and two in the trunk area, along with the original Prius traction battery.

The system uses the additional 2 kWh battery pack (an optional 4 kWh pack is also available) to continually feed juice to the original Prius battery. A "PHEV" switch is added, which fits into an existing spot on the dashboard. The switch awakens the "try EV mode" software that resides in the 2004 to 2009 Prius computer. Toyota installed that trigger wire as a standard feature of Priuses in Japan, but left it dormant for North American Priuses. (The EV button/mode is standard on the third-generation 2010 Toyota Prius—although the battery pack is still small at 1.4 kWh.)

Enginer's PHEV switch turns on the battery pack, the battery management system, and a DC-to-DC "boost" converter—the Enginer's "secret sauce," according to Guzyk. It takes direct current from four 12-volt batteries and converts it to 240 volts. "The Prius battery charges at approximately 240 volts, but we save a lot on cost by using a 48-volt battery," Sherwood explains. "It's a standard battery size. With the converter, you need fewer cells to get a higher voltage."

As 3Prong was finishing the conversion, I had a 120 VAC power source installed at my driveway, with a retractable industrial extension cord tucked away behind a small hinged-door outlet box on the side of the house. I couldn't wait to plug in, charge, and then hit the road.

The new battery and charging module drops in above the spare tire.

Above: The male AC receptacle and its cover are the only external signs of the installation.

Left: The module placement makes accessing the spare tire more difficult, but allows a clean-looking installation.

Plug-In Performance

On the first mile-and-a-half of the inaugural trip—a 5-mile jaunt to pick up Chinese food to celebrate the conversion—the car topped out at 99.9 mpg, as high as the Prius's dashboard display can go. But as expected, the auxiliary battery couldn't keep up with the all-electric demands, so the car reverted to standard hybrid mode, using the gas engine to power the wheels and recharge the stock Prius battery. Think of it as a bathtub draining about four times faster than you can fill it. By the time I pulled back into my driveway—the crispy Szechuan chicken still warm—the dashboard display read 78.5 mpg. Still pretty sweet.

Of course, the mpg reading on the dashboard only tells you how much gasoline is used, and doesn't reflect the use of a small amount of household electricity. In effect, the dashboard reading is slightly overstated, but the extra 2 kWh, at $0.11 per kWh, is a small price.

As I drove the next few days, the same pattern continued. The Prius acted like an electric car for a mile or so, but then the auxiliary battery struggled to refill the factory Prius battery. Stoplights were a welcome opportunity for the Prius battery to catch its breath. Sometimes the car wouldn't go into EV mode at all, despite having a fully charged battery. Like all the other aftermarket conversion products, the Enginer system does its best to predict how the Prius will respond to the extra juice, but it's not an exact science. Some trips would tally a remarkable 85 or 90 mpg, while others delivered a more modest 50 or 55 mpg.

Even when the car wouldn't go into electric mode, it clearly benefited from the second battery. Techniques for maximizing mileage with conventional hybrids—such as feathering the accelerator or lifting your foot off entirely, then very lightly easing back in—were even more effective post-conversion.

Was it worth it? Well, that depends on how you see the extra attention required—remembering to plug in the car at night, using fancy footwork on the accelerator, flipping the PHEV off and on to engage the EV mode—and a less accessible spare tire under the new auxiliary batteries. My 10-year-old son Isaac compared the ups and downs of the Prius battery to the "manna bar" in several video games that he plays. "Every time you use special ability or spells, your manna goes down," explains Isaac. "When you just use normal attacks that don't cost any manna, your manna will regenerate." And that's how I felt. The extra benefits from the conversion felt like manna. Not as predictable as you would want, but great when it works.

(continued on page 60)

Voilà: After the installation, not even a trace of the battery modification is evident.

UPCOMING PLUG-IN HYBRIDS

Chevrolet Volt—General Motors calls the Volt an "extended-range electric vehicle." That's essentially marketing spin for a plug-in series hybrid. The engine doesn't drive the wheels—it only kicks in to power a generator to sustain the battery pack's charge, providing another 300 miles of range. And that only happens once the battery is exhausted. For the first 40 miles or so, the Volt burns no gasoline, drawing energy from a 400-pound, 16 kWh Li-ion battery. Energy from that pack powers a 150-hp electric motor that provides all the propulsion.

The Volt's price tag is a source of much debate, with recent estimates around $40,000. The company plans to build 10,000 Volts the first year, beginning in late 2010, and perhaps as many as 60,000 in 2011.

Fisker Karma—The Fisker Karma is a $87,000, 400-hp, four-seat sports car. It's expected to be the first plug-in hybrid on the market, and the world's first *luxury* plug-in hybrid. In a 2009 interview with founder Henrik Fisker, I asked who would be likely to buy the Karma. "I think our market is everybody who has a little bit of conscience," he said, "and enough money to buy it."

Like the Chevrolet Volt, the Fisker Karma is a plug-in series hybrid that uses electric power to turn the wheels. The 22 kWh Li-ion battery pack, designed by Canada's Advanced Lithium Power, promises 50 miles of electric range. A 2.2-liter GM Ecotec four-cylinder engine powers a generator that makes enough energy to add 250 more miles. The company expects annual production to reach 15,000 within two years of launching in mid-2010.

Ford Escape Plug-in—Ford is claiming that the plug-in hybrid version of the Escape, a small SUV, can travel 30 to 35 miles using little or no gas—if driven in town and if the batteries are charged by being plugged in for six to eight hours. After those 30 or so miles, the vehicle reverts to being a conventional Escape Hybrid—which is the most fuel-efficient SUV in the United States, according to EPA fuel economy ratings.

The Escape Plug-in Hybrid uses a relatively small 10 kWh Li-ion battery pack and it can use either electricity, gasoline, or both, as required by the driver's needs. The Ford Escape Plug-in Hybrid is expected to hit showrooms in 2012.

GM's Crossover Plug-in Hybrid—The vehicle was originally conceived as a Saturn Vue in 2007, became an unnamed Buick model in August 2009, and two weeks later was a technology in search of a vehicle.

GM maintains its commitment to a plug-in crossover SUV, but the details are yet to be announced. The plug-in Vue was going to utilize a modified version of GM's two-mode hybrid system, plug-in technology, and an advanced Li-ion battery pack—to offer electric-only propulsion for more than 10 miles. The power train was to be two permanent-magnet motors and GM's 3.6-liter V6 gasoline engine with efficient direct fuel injection.

Toyota Prius Plug-In Hybrid—By January 2010, Toyota was expected to have the first 500 official Prius Plug-In Hybrid prototypes on the road. The United States got 150 of the test vehicles, which use Li-ion batteries—not the NiMH packs that Toyota says are the current and long-term solution for conventional hybrids. This kicks off a three-year effort to get data on how plug-in cars fare in the real world: how they're charged, how their batteries perform, and what sort of mileage they get.

Toyota is targeting 2012 as a release date. When the company unveiled the car at the 2009 Frankfurt Auto Show, it released basic stats: all-electric driving mode of 12.5 miles at speeds up to 62 mph, carbon dioxide emissions cut to less than 60 grams per kilometer, and full recharging in about 1.5 hours from a 230-volt supply. Reuters reported that Toyota plans to sell the plug-in Prius at a price close to that of the all-electric Mitsubishi i-MiEV, which is going for about $48,000 in Japan, but I expect a much lower price.

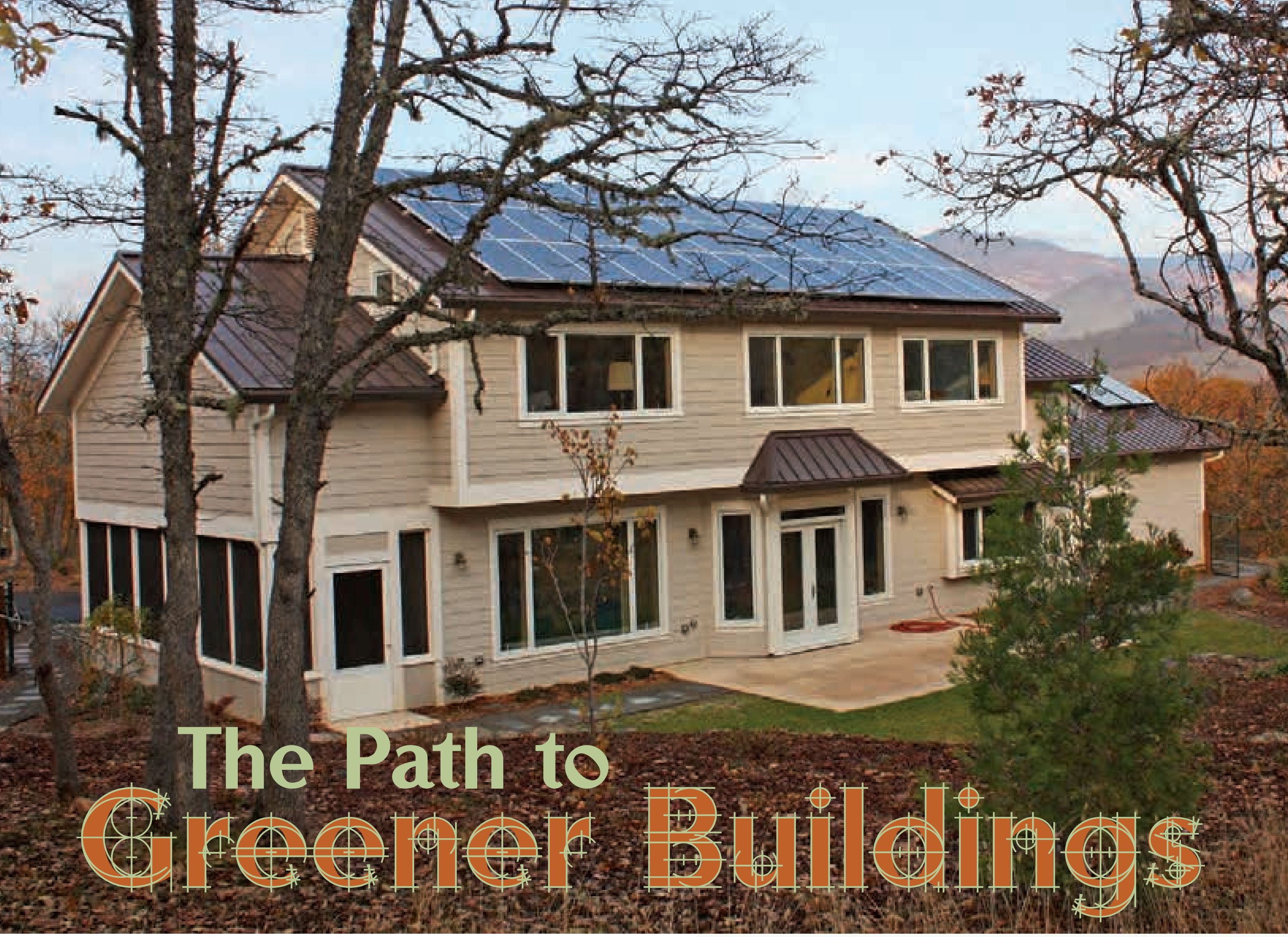
After one month of driving, the car's average mileage jumped from the mid-40s to almost 60 mpg. How does that pencil out in terms of return on investment? To answer that, I asked accountant Bob Susich, based in nearby Moraga, California. He was the very next 3Prong customer, converting his Prius using the 4 kWh Enginer system that sells for $4,500 in California. Susich also has an 8 kW photovoltaic system on his house.

"With today's prices, I can look at this as a seven-year investment. Run the car 120,000 or 130,000 miles, mainly around town, and it becomes break-even," says Susich. "If you believe that gasoline in three or four years will be $5 or $6 a gallon, then it's a very rapid payback." But Susich isn't trying to save money with his conversion—he just doesn't want to *lose* money. "There's an ecological dimension as well. If I can have no carbon footprint or reduce it dramatically, well, why not?"

The financial and energy ledger doesn't quite balance out for me—maybe because I don't have a PV array yet, but also because the Enginer system, while relatively inexpensive, does not reliably supply the level of electric power I was seeking. However, I'm very encouraged by the growing field of aftermarket systems (which are all more powerful, but pricier, than Enginer's). That at least four distinct plug-in conversion systems exist indicates that a market is emerging—and plug-in hybrids and electric cars from major car makers are right around the corner. Based on my particular driving cycle, the Enginer system resulted in a 40% to 50% mpg improvement. That's great. The experience only intensified my desire for a more robust electric-drive car and made me more eager to go solar at home. My conversion is about more than adding batteries to a Prius. It's a conversion to the belief that cars can and should run on sunshine.

Access

Bradley Berman (brad@hybridcars.com) is the founder and editor of www.hybridcars.com and the forthcoming www.plugincars.com, launching in spring 2010. He writes about hybrid cars and other advanced fuel-efficient vehicles for *The New York Times*, the Reuters news agency, the *Detroit Free Press*, and other publications. Through his writing and media work, Berman promotes a greater understanding of the importance of sustainable mobility.



The Path to Greener Buildings

by Andy Kerr

Once you decide to build green, don't look back. But before you go this route, know where you're going—and who you'll be bringing along for the ride. Here are some tips for navigating along the ever-evolving path of green building.

Even if you've hired a good architect, designer, and/or builder, it will be helpful to know as much or more about green building than they do. They might know more about basic building design and construction, but you will need to become the green building expert. The more you know, the easier it will be for you to communicate your preferences and priorities effectively—and to observe whether your wishes are being carried out during construction.

Research Fully

Once I decided that building "green" was something that interested me, I hit the books and the Web. I read, and I read, and I read some more—probably 50 or more books altogether. (See "Green Building Resources" sidebar.)

However, when it comes to green building, books can fast become outdated, since new materials and designs are revolutionizing green building quickly. The single best investment in my learning process was a $199 annual subscription to www.buildinggreen.com, an independent source for information on green products and news about the green building industry.

Expect to build your green building library before you build your green house.

All Photos Ben Root

The author reviews the professionally customized home plans, which started as a standard, ready-made design.

What Green Means

Crack open a few books and scan some magazine articles and you'll quickly realize that what constitutes "green building" can vary greatly. For some folks, it means using recycled materials. For others, it can mean achieving a highly efficient building envelope. Alex Wilson, the publisher of www.buildinggreen.com, uses the term "green building" to describe building design and construction that has some or all of the following characteristics:

- Minimizes adverse impacts on local, regional, and global ecosystems
- Reduces reliance on automobiles
- Uses energy efficiently
- Conserves water
- Built environmentally responsibly, with low-impact, durable, and low-maintenance materials
- Helps occupants recycle "wastes"
- Comfortable, safe, and healthy for occupants

My research braced me for one of the realities of building a green home—the tremendous time commitment. Green building involves tailoring specific strategies to your individual project, climate, and location. Unless you have a green building consultant at your beck and call, you must be intimately involved in the process from start to finish.

Consult with Experts

Unless you have extensive drafting and design experience, there are two routes you can take when designing a home: hire an architect or hire a designer.

An architect usually has more credentials, but their fees tend to be higher because they stay with the project until completion and oversee the builder during construction. Some building codes require an architect's approval on plans, so you may not have a choice.

A designer draws the plans to the owner's specifications and to satisfy code compliance, but then hands off the plans to the builder and is no longer involved with the project. Designers are typically less expensive, but you'll be the one responsible for conveying necessary information to your builder once the plans are drawn.

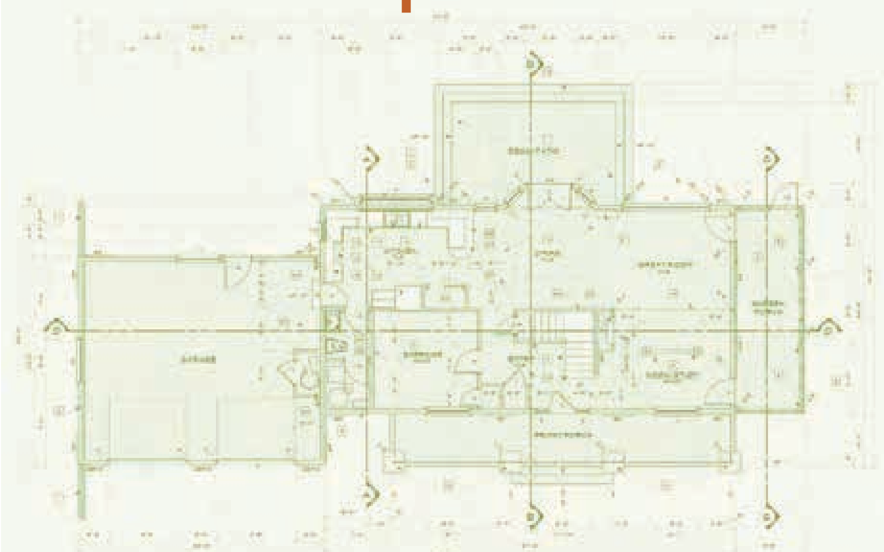
Even though you've read through piles of books, you may also want to retain a green building consultant. Before you hire them, ask about professional certifications, academic credentials, and field experience. The U.S. Green Building Council's LEED Professional Accreditation and the National Association of Home Builders' Certified Green Professional are two examples of certifications. Expert forums can also be great resources. The forums of both www.buildinggreen.com and www.greenbuildingadvisor.com are popular sites where you can interact with experienced, knowledgeable experts.

Passive solar design was a key element of this green home. Large, south-facing windows admit winter sun, while adequate overhangs prevent summertime overheating.

Choosing a Plan

Ideally, you'll have chosen a building site with solar access. Numerous online purveyors tout "solar" house plans. But buyer beware: More than half of the so-called "solar" house designs that I looked at didn't even have a compass symbol on the plan that oriented the house toward the sun. By understanding simple passive solar strategies, you'll be able to find the plans that are likely to work. After surfing several Web sites, I purchased floor plans for a passive-solar home to use as a starting point, and turned over the electronic version to our designer, who brought it up to local code and modified it to suit our needs.

Kerr "Greenprint"



From my research, I came to accept one of the basic tenets of green building: Small is beautiful. Even a sloppily and unsustainably built small house can cause less environmental damage than a thoughtful and more sustainably built large house. A small house typically consumes fewer resources during its construction and requires less energy to operate. Although my house is not "small," at about 2,500 square feet, it's about average for residential construction in the United States. It serves as a home office for two people and includes an exercise room—two features that eliminate driving to work or the gym.

Seeking Certification

One path to a green home is to go through a certification process—the parameters defined by the program can help lead your design. Perhaps the most widely known program is the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED), which awards the home with an overall rating based on sets of criteria. Depending upon the number of points received, a LEED home is classified as Certified, Silver, Gold, or Platinum.

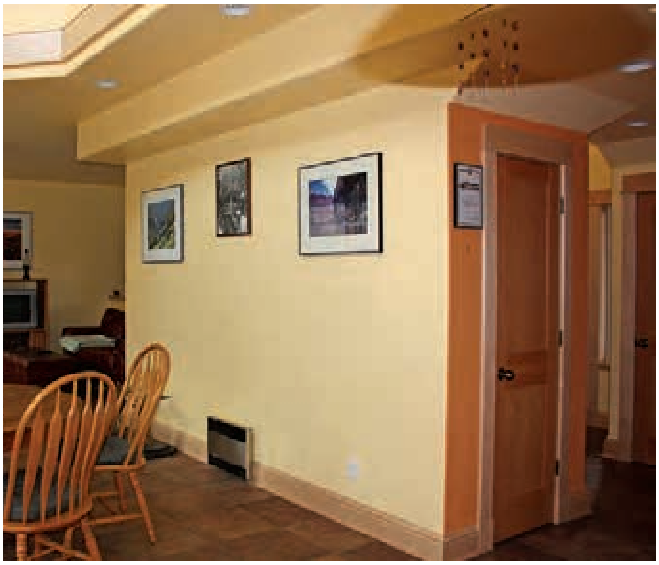
The LEED program, like most other green certifications, requires on-site evaluations and extensive documentation, which adds significant time and expense to the project. (For instance, LEED registration and certification for a single-family home costs about $525 and typically requires several site evaluations over the course of construction.)

There are benefits to participating in a certification program. First, you'll have another set of eyes on your project to spot any mistakes that could compromise the home's performance. Second, a home with an independent "green" certification may be more marketable and command a premium if you ever decide to sell. Third, certifications may be needed to qualify for incentive programs, which offer cash rebates or tax credits that help recoup some of your building costs.

LEED certification is most useful in assuring a buyer of a green home that it is indeed green. Because I participated at every step in the construction of my house, I felt that I did not need those assurances. However, I did review the LEED standards and sought to conform to most. While the certification standards and process are generally excellent, I think that the LEED new home certification system short-changes renewable energy by limiting that aspect to a total of 10 points, or roughly 1 point for each 3% of the home's power

Countertops made with recycled paper and energy-efficient appliances are just some of the home's eco-friendlier features.

A concrete block wall provides additional thermal mass to moderate temperature fluctuations in the home.



Triple-pane, argon-gas-filled windows with fiberglass frames were selected for their performance and durability.

that is renewably produced. If powering 30% of a new home by renewable energy is a green thing to do, then powering 100% of a new home should be 3.3 times "greener" and reflected as such in the standard.

While I decided against the time and expense of pursuing LEED certification, I did choose to pursue certification required for obtaining tax credits through Earth Advantage, a nonprofit green building program based in the Northwest.

Addressing the Envelope

The envelope is the house's thermal barrier between the comfortable and habitable inside and the vagaries of the weather. You'll want to prevent heat from radiating or conducting through the walls (out or in), and prevent convection losses by thoroughly sealing cracks, ducts, and penetrations.

No matter what construction method you choose—stick-frame, insulated concrete forms, structural insulated panels, straw bale—you'll want to make sure your house is well insulated and protected against air infiltration. Construction details, like minimizing thermal bridging, are vitally important.

Specify adequate levels of insulation in all parts of your home—and don't rely on just meeting the building code. Insulating beyond code requirements will save you energy *and* money.

Custom thermal shades reduce heat loss through the windows.

Green Building Resources

Books

- ***Builder's Guide to [X] Climates: Details for Design and Construction*** by Joseph Lstiburek (Building Science Press, 2009) • Not one book, but several different titles, with "X" being "Cold," "Hot-Humid," "Hot-Dry & Mixed-Dry" or "Mixed-Humid" climates, this series offers a general guide to good, *modern* (which includes green) construction techniques with lots of detailed construction drawings.

- ***Your Green Home*** by Alex Wilson (New Society Publishers, 2006) • A must-read book—some call it the bible of building green.

- ***The Sun-Inspired House: House Designs Warmed and Brightened by the Sun*** by Debra Rucker Coleman (Sun Plans Inc., 2005) • An excellent primer on passive solar homes and choosing the best plans for your site. Architect Coleman also sells house plans at www.sunplans.com.

- ***The Solar House: Passive Heating and Cooling***, by Daniel D. Chiras (Chelsea Green, 2009) • A detailed exploration of passive solar homes.

Web Sites

- **www.buildinggreen.com**—Examines a product's manufacture, life cycle, pollution, recyclability, quality, and price, and puts it in layperson's language. This Web site is widely respected as a trusted resource for accurate, unbiased, and timely information.

- **www.regreenprogram.org**—This green home remodeling site is sponsored by the American Society of Interior Designers' Foundation and the U.S. Green Building Council.

- **www.buildcarbonneutral.org**—Lots of sites can estimate the carbon footprint of operating your home, but this site helps you estimate the carbon footprint of building.

- **www.buildingscienceconsulting.com**—Free information including construction details, moisture management, and green building practices.

- **www.efficientwindows.org**—Use their window selection tool to compare the U-values, SHGC, and energy costs for windows from various manufacturers, and get window guidelines from LEED and other programs.

- **http://windows.lbl.gov**—Provides free, downloadable software that helps you calculate and compare windows.

- **www.greenbuildingadvisor.com**—An effort of *Environmental Building News* and *Fine Homebuilding*, this site provides a forum for answers by green building experts, a searchable green product guide, construction detail drawings, and downloadable construction strategy checklists.

- **www.pathnet.org**—Includes design and construction guides, a searchable technology inventory (maintained by the National Association of Home Builders Research Center), and field evaluations of various technologies.

- **www.ornl.gov/sci/roofs+walls/AWT/InteractiveCalculators/rvalueinfo.htm**—Calculate the whole-wall R-value of your building method.

Fiber-core interior doors with FSC-certified wood veneers are tasteful, sustainable choices.

Operable windows placed high in the second-floor rooms provide ventilation using natural convection.

An energy recovery ventilator introduces fresh, conditioned air into the well-sealed home, with little heat loss.

The envelope is a complex unit, typically made up of several materials—siding, sheathing, windows and doors, framing, insulation, and drywall—and whole-wall R-values will give a more accurate picture of the home's thermal performance than just looking at the value of the insulation within the walls. While Energy Star recommendations provide a starting point, Oak Ridge National Laboratories whole-wall R-value calculator can help you quantify your choices.

Well-constructed and super-insulated windows and doors should also be selected. Energy Star (ES) requirements are just a starting point as windows are available that trump the ES criteria. The three main values you'll want to consider are:

- Full-frame U-factor measures how quickly heat passes through the window unit and is the reciprocal of R-value (the resistance to heat flow). Energy Star guidelines can help you select the U-value for your climate.
- Solar heat gain coefficient (SHGC) is the fraction of heat from the sun that enters through a window. Until this year, ES specified an SHGC of 0.30 or below for all windows—no matter their location within the house. However, that recommendation has been revised to account for south-facing glazing on passive solar homes, which require a high SHGC to perform optimally. Finding affordable windows with high SHGCs can be challenging. Ask your window manufacturer about hard-coat low-E windows and what the highest SHGCs are for their various lines. Canadian fiberglass window manufacturers generally can provide glazing with higher SHGCs, and, so far, at least one U.S. manufacturer of fiberglass windows—Serious Windows—offers windows with higher-than-typical SHGCs.
- Air leakage (AL) measures the amount of air infiltration through the unit, and will vary by manufacturer and by window type. This information can be difficult to find in the manufacturer's popular literature. Typically, you'll want to choose a window with an AL less than 0.30 cfm per square foot. Leakage through windows and doors are only part of your worries—ensure that potential air leaks in the envelope are sealed during construction.

Be prepared to pay a premium for high-performance windows. My triple-pane, argon-filled, fiberglass windows cost 3.6 times as much as code-compliant windows, but I will recover the difference in energy savings over the long term. Plus, the fiberglass frames of my windows are durable, don't warp like wood, and don't have the toxicity issues associated with manufacturing vinyl windows.

Design for Passive, Then Add Active

A well-designed, well-insulated house is a starting point for saving energy. But the more passive strategies you employ, the more energy you'll save. I sited our home's long axis to receive the winter sun and then specified latitude-specific overhangs to keep the hot summer sun out.

Passive space heating allows the sun's warming rays to enter the house and warm the air and the thermal

The well-insulated, well-sealed house requires no central furnace. Twelve 500-watt radiant heaters do the job when passive solar can't.

mass—concrete, tile, etc.—during the heating season. Without adequate thermal mass, the sun over-warms the air in the house like inside a car. But properly sized and installed thermal mass provides a heat sink for solar gain and can also help keep a house cool in summer.

To estimate the supplemental heating load (the home's main heat source is the sun), I hired a professional engineer to evaluate my plan with Energy-10, a building analysis program that factors in passive solar heating and cooling, natural lighting and ventilation, windows, wall insulation, shading, mechanical equipment, and other variables. The house is designed well, and built and insulated well enough that it takes only a few strategically placed electric heaters to warm the house on the coldest days—no central heating system was needed. The energy load of those heaters is equivalent to running three toasters.

Good passive-heating design can also be good passive-cooling design, eliminating the need for air-conditioning. Here in Ashland, Oregon, summer days are often in the 90s and 100s. However, almost every night, the temperature drops into the 50s. Proper shading and insulation keep most of the sun's heat out of the house, and what does get in is mostly absorbed into the thermal mass, which helps moderate the inside temperature.

In the evenings, natural ventilation (high windows on the second floor placed just for that purpose) allow the warmed interior air to move outside, as cool outside air is drawn in from ground-floor windows. If additional ventilation is necessary, two whole-house fans move hot air out of the house through the attic.

My designer was nervous about foregoing air-conditioning, noting that there are some times when the nights don't cool off. However, I reasoned that the money I would have spent on central air-conditioning was better directed toward efficient design, conservation, and passive cooling strategies. If there are a few hot days where passive cooling isn't enough, I'll either head for the beach or the mountains or hunker down with mint juleps on the porch.

Besides the whole-house fans, one mechanical system that is important to a high-performance house is an energy (or heat) recovery ventilator (ERV or HRV). An efficient house is

What Makes My Home Green

Design Strategies

- Sited for solar access, with the long axis of house oriented east-west
- Passive solar floor plan with 10% south-facing glazing and 4 inches of thermal mass in the concrete floor, poured over 8 inches of XPS rigid-foam insulation (R-value of 40; local code is R-15)
- Sized-for-latitude overhangs allow winter sun in for solar heating, but keep it out in the summer
- Windows strategically placed to take advantage of natural ventilation
- Windows minimized on east and west walls to avoid heat buildup from early- and late-day summer sun

Construction Details

- 2 x 6 stick-frame construction, spaced 24 inches on center, Forest Stewardship Council-certified wood
- Walls insulated with polyurethane foam boards and spray foam within the walls; 1-inch-thick polyisocyanurate board serves as a thermal break between the outside of the studs and the siding for a total of R-40 (code is R-22)
- Ceiling insulated with 12 inches of polyurethane board and polyurethane foam for a total of R-71 (code is R-38)
- Standing-seam metal roof
- Triple-pane, argon-gas-filled, fiberglass-frame windows. South-facing windows have SHGC of 0.63 and a U-value of 0.16

Mechanicals

- No air-conditioning: Opening windows at night and closing them during the day is typically sufficient
- Two Tamarach Technologies whole-house attic fans can flush out hot air when needed
- Ceiling fans throughout aid cooling in summer
- Panasonic WhisperGreen bathroom fans
- High-efficiency energy recovery ventilator provides adequate exchange between indoor and outdoor air
- Solar hot water system offsets about 68% of the electrical water heating
- 7.2 kW grid-tied PV system with battery backup provides 100% of electricity needs

Finishes & Products

- PaperStone countertops made from recycled paper and nonpetroleum binders
- Cabinets of FSC-certified wood and formaldehyde-free plywood
- No-VOC paints, adhesives, and finishes used throughout
- FSC-certified Oregon white oak flooring
- Humabuilt (www.humabuilt.com) doors, made with wheat hull (interior) and wood veneer (exterior)
- FSC-certified wood trim and moulding
- Insulated WindowQuilt (www.windowquilt.com) shades
- Ridgeline, gable, and soffit vents keep attic area cool and dry
- Delta H_20 Kinetic technology low-flow showerheads
- Caroma low-flush (1.6 gpm) toilets

Two solar thermal collectors offset 68% of water-heating energy loads.

tightly constructed, with little air exchange between the inside and outside. The American Society of Heating, Refrigeration, and Air-Conditioning Engineering provides procedures for determining whole-house ventilation rates in its standards.

An ERV or HRV exchanges stale indoor air for fresh outdoor air, but minimizes the loss of heat (in winter) or gain of heat (in summer) in the process. The energy required to run these units is a tiny fraction of the energy saved by not losing heat or "coolth" to leaky construction.

My heating, ventilation, and air-conditioning contractor discouraged the ERV I'd specified, and tried to direct me to a less expensive HRV that he was familiar with. I wanted the more efficient ERV, because even though it cost more initially, its high-efficiency motor and heat-exchange design would save me money in the long run. He still wasn't convinced, but the unit I wanted qualified for a $300 state tax credit, and his recommendation gleaned only a $150 tax credit. In any case, since I was the customer, I won the argument.

SHW systems can round out a green home, and offer both up-front capital and ongoing operational savings and benefits, especially if you can take advantage of tax credits or other incentives. The cost of my SHW system was $3,150, rather than $1,190 for a "conventional" tank-style electric water heater installation. The higher initial cost of $1,960 for going solar was more than offset by the incentives: a $1,500 state income tax credit; a $1,000 rebate; and a $945 federal income tax credit. Factoring in these subsidies meant that I was $295 *richer*—even before factoring in energy savings. My 120-gallon single-tank system stores sun-heated water and also uses electricity to heat it when sunshine is inadequate. The oversized tank allows both optimum use of the sun and provides enough electrically heated water on cloudy days. Conventional tanks have two heating elements. In my system, the lower heating element was replaced by the heat exchanger from the solar collector.

Choosing Green Materials

Green building materials do not overcome the environmental sins of bad design. Thinking through all the major factors (orientation, shading, lighting, insulation, etc.) beforehand will result in an integrated and complementary design that doesn't have to cost much more than "conventional" designs.

Indoor air quality was a critical factor in our finish materials selection. A basic principle in green building is to avoid toxic chemicals. Paints with low or no volatile organic compounds (VOCs) are a good start, but read the material safety data sheets available for each product from manufacturers. Look for indicators of problems, such as special handling requirements and warnings about toxicity. For example, I used American Formulating & Manufacturing paint, which is zero-VOC and also free of formaldehyde, ammonia, crystalline silica, and other chemicals commonly found in paint. Even some low- or no-VOC paints still might contain lead—yes, in the United States, "lead-free" paint does not necessarily mean free of lead—it just means it's below the legal limit of 0.5% of a product's dry weight.

As you'll discover, every design detail in a green home requires significant research. For example, consider the kitchen and bathroom counters. There are lots and lots of options out there—many of which we quickly disregarded because of their toxic and/or unsustainable elements. After weighing various options, we chose PaperStone, which is made from Forest Stewardship Council (FSC)-certified post-consumer recycled paper and uses nonpetroleum cashew-nut hull oil as a binder. A friend questioned our decision, pointing out that we could buy Italian marble for as much as we were spending on the PaperStone. True enough, but the environmental value of the PaperStone was worth more to us than the finest Italian marble. We particularly appreciated that the product was manufactured just a few hundred miles to the north of us, and didn't need to be quarried out of the ground and shipped across an ocean and a continent to reach us.

Some of the bigger decisions come easier—once you accept that you will spend more for green materials. Specifying FSC wood throughout cost 1 to 2% more than conventional wood products. The 50-year-warranted metal roof cost more than a 20-year asphalt shingle roof, but will last more than twice as long. Plus, the metal can be recycled, while asphalt shingles would end up in the landfill someday. If I lived in a hotter climate, I would have chosen a more reflective roof to reduce heat gain in the summer. However, my roof insulation is nearly three times what the building code requires and the attic is vented so excessive heat gain through the ceiling is not an issue.

Having a home office cuts out the daily commute. When transportation is needed, the author drives his hybrid-electric car.

Probably the single-most exasperating factor I found in building a green house was the limited local availability of green products and competent subcontractors. There was no local insulation contractor that could spray the insulation I wanted (there now is). The windows I specified came from Canada, and the product was far better than their service (similar ones can now be had from Colorado and elsewhere). Many green products had to be special-ordered—a process that didn't always work smoothly.

Accounting for Going Green

Determining just how much it costs to go green is not easy. For example, spending more on an integrated design from the beginning means you spend more up-front on the building envelope (i.e., more insulation, better doors and windows, etc.). However, this also means you spend less on heating and cooling in the long run—both in terms of initial capital costs (no expensive equipment) and ongoing operational costs.

The estimates vary, but green building typically costs from 1 to 10% more than conventional construction. Think about it this way: The money you'll save later as a result of lower operating costs can be applied to greener materials and products today. I'm coming out ahead by going green, even without considering other benefits, such as indoor air quality. In making decisions for the home, I didn't worry as much about the cost-efficiency of each product choice as I did the cost-efficiency of the home's overall design and construction.

Depending upon your state, tax credits may help offset the additional costs of efficient building and green materials. In Oregon, I was able receive tax credits and utility rebates for purchasing a refrigerator, washing machine, and dishwasher that exceeded the minimal Energy Star ratings, as well as get credits for PV energy production, solar hot-water heating, passive solar heating, building a high-efficiency house, and installing an ERV. Your builder is also entitled to a federal tax credit (which should be reflected in their final bill) for building an Energy Star home, should you choose to go that route.

When it comes to building, being penny-wise often results in being pound-foolish. Putting your money into what counts—solar design and lots of insulation, plus high-performance windows and doors—will result in both short-term and long-term payoffs in overall comfort, livability, energy savings, and financial savings.

Access

Andy Kerr (andykerr@andykerr.net) is czar of The Larch Company (www.andykerr.net), a conservation organization that represents species that cannot talk and humans not yet born, with offices in Ashland, Oregon, and Washington, DC. All profits are dedicated to the conservation and restoration of nature. A deciduous conifer, the western larch has a contrary nature.

Building a Solar

by Andy Kerr

A few years ago, my wife and I decided it was time for an upgrade. After living in an older bungalow for several years in downtown Ashland, Oregon, we wanted to build a new home that reflected our green values and gave us a little more elbow room. We found the perfect 5-acre lot in the rolling hills on the outskirts of town, with the southern exposure we needed for our solar-inspired design and the country feel we longed for.

One of our primary objectives was to produce as much energy as we consumed. My work as a conservation consultant partially inspired our mission for a net-zero home and, as it happens, also made it possible for the economics of this venture to work. We were able to take advantage of a mix of residential and commercial rates and incentives, since the new home would also accommodate the office for my consulting business—Larch Company, a for-profit conservation organization. Here's how we made our PV system pay off.

Considering the Variables

Having had solar hot water and photovoltaic power systems on former homes, I had some sense of what to expect, but working with new construction came with special challenges. While new construction allows one to freely work on both sides of the supply and demand equation, it also means you have no energy history to work with. I had to guesstimate my annual energy consumption to compute system sizes. The usage history at my former home provided a good starting point, but I had to take into account several new variables.

My new home would be slightly larger, but far better insulated and more energy efficient. Heat losses would be minimized by a highly insulated envelope with triple-pane argon-filled windows and tightly sealed doors. Newer energy-efficient appliances would also lessen the load.

Whereas my old house relied on a natural gas furnace that used electricity to operate the blower, my new house would depend almost entirely on the sun for its heat, with a handful of small convection electric wall heaters providing supplemental heat; an energy recovery ventilator to help keep air fresh; and a propane direct-vent wall heater for backup when the grid goes down. My wife and I decided to forego air-conditioning and central heating, and instead put our faith in a thoughtful passive solar design to moderate the temperature in the house.

We were able to take advantage of a mix of residential and commercial rates and incentives, since the new home would also accommodate the office for my consulting business...

I hired an engineer to evaluate my building plan with Energy-10, a building analysis program that factors in passive solar heating and cooling, natural lighting and ventilation, windows, wall insulation, shading, mechanical equipment, and other variables. According to the evaluation, any supplemental heat demand for the new home would be low enough to be satisfied by electric convection/radiant heaters, with no fans. Additionally, I needed to account for a well pump—an additional energy cost of rural living.

Business

Trading Renewable Energy Credits

Renewable energy system owners can sell the environmental attributes of their systems in the form of renewable energy credits (RECs)—also known as green tags. These tradable commodities are sought by public and private entities that are required by law to offset a portion of their greenhouse gas emissions. In Oregon, as a condition of the Energy Trust subsidy, commercial and business customers own 100% of their systems' RECs for the first five years, and then the Energy Trust owns them for the next 6 to 20 years. (Note: Incentives are always in flux, and the terms have changed even since my installation in 2006.)

Larch Company sold its green tags for the first two years to 3Degrees Energy, a REC broker. At 5 cents for each solar kilowatt-hour produced, the RECs generated $444 in taxable income each year. While it's not much in the grand scheme, every penny counts.

By selling off all environmental attributes of the PV system to 3Degrees, Larch Company cannot claim that its electricity is green, climate neutral, or the like. However, I maintain the company's right to make green claims by buying green tags from Bonneville Environmental Foundation (BEF), a local nonprofit organization. Each year at tax time, I use the foundation's online carbon calculator to determine my carbon tax, based on the amount of electricity, propane, gas, gasoline, and jet fuel my family and business uses throughout the year. Then I pay my private carbon tax—usually $1,500 per year, which is tax deductible either as a business expense or as a personal charitable contribution, if you don't develop the venture as a business. A REC is measured as 1,000 kWh of electric energy produced in a CO_2-free manner. Prices vary by broker. 3Degrees, for example, charges $15 (or 1.5 cents per kWh for an REC for an unspecified mix of wind, biogas, landfill gas, biomass, geothermal, solar, and low-impact hydroelectric power), while BEF charges $20 (100% wind power), $27 (50% wind, 50% solar) or $35 (100% solar) for the same amount of "green" electricity.

All Photos Ben Root

The author's battery backup system provides electricity to dedicated loads when grid power is unavailable.

Another consideration was the different policies of my new investor-owned utility, Pacific Power. At my former home in Ashland, the city's municipal utility paid me for excess generation, and it made sense to oversize the system. When I generated and sold more energy to the utility than I bought at the end of the annual accounting period, I received compensation for the surplus, which usually amounted to about $150 per year.

Pacific Power only provides standard net metering as required by law and does not pay customers for excess

Grid-direct and battery-based PV systems share the same wall space. While three of the meters shown are PV production meters, the meter at the upper left is simply to measure kWh consumption of the electric space heaters.

generation. Rather, it "donates" any surplus to low-income energy-assistance programs. Though generally a charitable person, I wanted to scale my consumption as close as possible to—but not over—my production.

Sizing the System

I chose to work backward, from the supply side, and told my installer to "fill it up." He took the dimensions of the south-facing side of the home's main roof and devised a plan for two arrays using 42 Mitsubishi 170 W modules.

Knowing that the grid occasionally fails and that I could not afford to be without power for my business and my house—particularly the well pump—I opted to spend extra for a backup battery bank. The added convenience, reliability, and peace of mind were, in my opinion, well worth the extra expense.

Thirty modules are wired in three series strings through a batteryless 5.1 kW grid-tied Fronius inverter that has a weighted efficiency of 94.5%, according to the California Energy Commission. The remaining 12 modules are hooked up to two OutBack inverters, which feed the grid but also charge the 390 amp-hour, 48 V battery bank located next to the inverters in the garage. Production losses from battery charging give the OutBack inverters a slightly lower efficiency, about 91%.

When the grid goes down, the OutBack inverters automatically pick up the loads, including the well pump, refrigerator, and most of the 120 VAC household circuits except the dedicated circuits for the dishwasher and treadmill. The 240 VAC nonessential major appliances—such as the dryer and backup water heater—are not connected to the OutBack inverters so are inoperable during outages. The battery bank is large enough to sustain the household for a few days, depending upon how frugal we are with our electricity use and how much the sun shines.

Tech Specs

Overview

System type: Grid-tied PV with battery backup

Location: Ashland, Oregon

Solar resource: 4.9 average daily peak sun-hours

Production: 822 AC kWh per month

Utility electricity offset: 109%

Photovoltaics

Modules: 42 Mitsubishi PV-MF170EB3, 170 W (STC), 24.6 Vmp, 6.93 A Imp, 30.6 Voc, 7.38 Isc

Array: #1: Three, 10-module series strings; 5,100 W STC, 306 Voc; one 12-module string, 2,040 W STC

Array installation: DP&W Power rail mounts installed on south-facing roof, 33° tilt (installed parallel to roof plane)

Energy Storage

Batteries: Eight Discover sealed AGM L16-type, 6 VDC nominal, 390 Ah at 20-hour rate

Battery bank: Eight 6 VDC nominal, 390 Ah total

Battery/inverter disconnect: 2 175 A breakers

Balance of System

Inverters: Fronius IG5100, 5,100 Wp, 150–450 VDC operating range, 500 VDC maximum, 240 VAC output; two OutBack GVFX-3648 inverters, 7,200 Wp, 42–68 VDC operating range, 68 VDC maximum, 120/240 VAC output

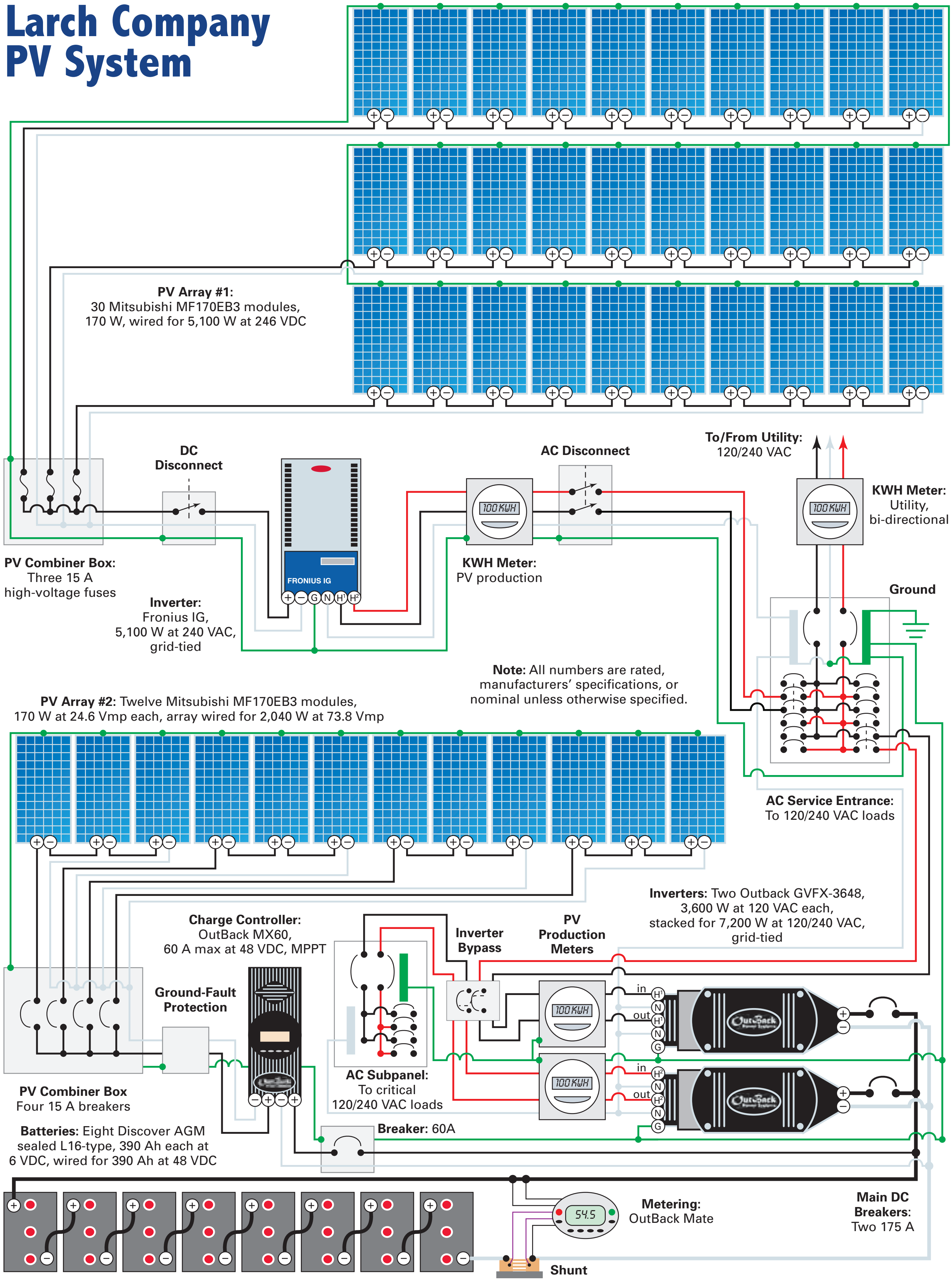
Charge controller: OutBack MX60

System performance metering: Fronius (built-in); two Austin International production meters wired into the output of the OutBack inverters (these meters are configured to accurately measure PV production and hence do not add in energy pulled from the grid to feed AC loads or to charge batteries); utility kWh meter

Getting Down to Business

My initial outlay for the battery backup PV system was $64,000 at the end of 2007. If I had not opted for battery backup, I could have saved about $12,000 and reaped almost another 2% return on investment.

Larch Company PV System



The PV system disconnect (left) next to the AC service entrance (middle) and the subpanel for loads backed up by the battery-based system (right).

Key to the economics of this system was its ownership by my consulting company. At the time, Oregon state PV subsidies were more generous for systems that are owned by businesses. Funded primarily by a public purposes charge on investor-owned utility energy bills, the Energy Trust of Oregon partially addressed this discrepancy by offering $2 per installed kWh to personal investors, versus $1.25 to $1.50 for commercial installations. The rate has since gone down, though.

Even with this rebate difference, it can still be more advantageous for businesses to own and operate PV systems in Oregon, so I set up my home-based consulting firm as the owner of the PV system. Larch Company essentially pays me (the homeowner) rent for using the south-facing roof of my home for its PV system, and then "sells" the electricity generated by its PV system to my household. As it happens, yearly energy cost is equal to the annual rent I charge Larch Company for rooftop space, so it's a wash on the books for tax purposes.

> Larch Company essentially pays me (the homeowner) rent for using the south-facing roof of my home for its PV system, and then "sells" the electricity generated by its PV system to my household.

This arrangement allows me to take advantage of tax rules that favor businesses. Because the system is business-owned, the capital and maintenance costs are a depreciable business expense that can be written off against taxable income—which can be taken either in one year or spread out, depending on the situation.

In addition to five years' worth of state income tax credits and the federal income tax credit of 30%, I was able to take accelerated depreciation on the cost of the system, which allowed me to deduct nearly the entire cost of the system from the consulting company's gross income for that year.

Assessing the Bottom Line

"Simple payback" is an unsophisticated financial accounting technique that determines the length of time required to recover your initial investment through reduced or avoided energy costs. My system achieves simple payback by the end of 2010, with a "profit" of $2,136 (see "Revenues" table.)

Using an internal rate of return, my estimated return on investment from the PV system is almost 20%. My financial model is 10 years, a common length for business investments. The system will be operational for the duration, as the modules are warranted for 25 years and will continue to produce energy that I don't have to pay for. After the payback period, it doesn't matter if electricity prices rise: 100% of my electricity costs will be fixed since the sun will continue to shine on my house without charge.

My model presumes the inverters and the batteries will last 10 years without repair or replacement. Since the batteries will only be used during times of grid failures, they will likely go the distance—and possibly longer. While inverters are complex electronics that can fail, the Fronius inverters are protected by a 10-year warranty.

Determining Consumption

In guesstimating the electricity demands of my new house, I started with the loads of my old house (which also included my home office) and then added a 10% factor for creeping loads—adding more electrical appliances over time. After modeling supplemental electric heating loads and water-

Kerr PV System Costs

Item	Cost
42 Mitsubishi MF170EB3 PV modules	$37,485
2 OutBack GVFX-3648 inverters	4,690
Labor	4,500
8 Discover AGM L-16 batteries	4,400
Fronius IG 5100 inverter	4,130
DP&W Power Rail mounts & hardware	3,910
OutBack miscellaneous boxes & hardware	1,508
kWh meters & disconnects assemblies	1,125
Outback MX60 charge controller	649
Miscellaneous electrical	520
OutBack Mate & Hub-4	490
Fused combiner box	228
Inverter & battery cables	220
Permit fees	86
Miscellaneous hardware	75
Total	$64,016

Revenues, Expenses & Estimated ROI

Item	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Initial system cost & salvage value	-$64,016	—	—	—	—	—	—	—	—	—	$19,334
Energy Trust of OR cash incentive (business) or	—	$8,925	—	—	—	—	—	—	—	—	—
Energy Trust of OR cash incentive (personal)	—	10,000	—	—	—	—	—	—	—	—	—
30% federal income tax credit (business) or	—	19,205	—	—	—	—	—	—	—	—	—
30% federal income tax credit (personal)	—	19,205	—	—	—	—	—	—	—	—	—
Oregon income tax credit (business) or	—	6,402	$6,402	$6,402	$6,402	$6,402	—	—	—	—	—
Oregon income tax credit (personal)	—	1,500	1,500	1,500	1,500	—	—	—	—	—	—
Federal & state depreciation (business only)	—	16,324	—	—	—	—	—	—	—	—	—
Sale of RECs to 3Degrees	—	444	444	0	0	0	$0	$0	$0	$0	0
Electricity sales	—	754	777	800	824	849	874	900	927	955	984
Income taxes (business only)	—	-359	-366	-240	-247	-255	-262	-270	-278	-287	-295
Net cash flow (business) or	-64,016	51,694	7,257	7,202	7,226	7,250	874	900	927	955	20,317
Net cash flow (personal)	-64,016	30,074	2,721	2,060	2,077	594	612	630	649	669	20,022
Accumulated cash flow (business) or	-64,016	-12,322	-5,066	2,136	9,361	16,612	17,486	18,386	19,313	20,269	40,586
Accumulated cash flow (personal)	-64,016	-33,942	-31,221	-29,161	-27,085	-26,491	-25,879	-25,249	-24,599	-23,931	-3,908
Year of simple payback (business) or	—	—	—	2010	—	—	—	—	—	—	—
Year of simple payback (personal)	—	—	—	—	—	—	—	—	—	—	—

Production & Variables	Amount
Estimated AC kWh per year	8,881
Grid electricity rate $ per kWh	$0.085
Estimated income (Year 1)	$754
Electrical rate annual inflation assumption	3%
Green tag rate $ per kWh	$0.05
Combined state & federal income tax bracket	30%

Bottom Lines	Percent
Internal rate of return (business) or	19.25%
Internal rate of return (personal)	-1.35%

pumping demands, I forecast a consumption of 8,400 kWh annually—and my planned PV system would produce 106% of my electrical power needs each year.

After the first year, it was time to see how my guesstimates measured up. Determining consumption requires data from meters installed for just that purpose: (1) the amount of power purchased from the utility; (2) the amount of PV power sold to the utility; and (3) the total annual production of the PV system versus actual consumption. At the end of the system's

Using an internal rate of return, my estimated return on investment from the PV system is 19.25%.

first year, I used 6,652 kWh from the utility and sent back to them 7,491 kWh—a surplus of 839 kWh. My system produced 9,867 kWh for the year—some of which the house consumed immediately.

After subtracting the 839 kWh net surplus, my total consumption was 9,028 kWh, or 7.5% more than I had originally estimated. That put the system's production at 109% of consumption in the first year—and in Oregon, any excess generation helps support underprivileged households through Pacific Power's low-income assistance programs.

The author at the utility meter, which recorded a 9% energy surplus last year.

As a business venture, the estimated internal rate of return is 19.25%. If it was a personal venture, it would be an estimated -1.35% internal rate of return. The primary reasons for the disparity are that Oregon's subsidies for PV systems installed by businesses are much better than for those installed by individuals and that a business can deduct the capital and maintenance costs of the system as a business expense.

As it turns out, the demand and the supply of my new system are about as balanced as one can get, even with the variability of sunshine and heat demand each year. If the slight surplus holds, I could always choose to set the thermostat at 72°F rather than 68°F next year.

Access

Andy Kerr (andykerr@andykerr.net) is a conservationist, writer, and analyst. He heads up the Larch Company (www.andykerr.net), a non-membership, for-profit conservation organization with offices in Ashland, Oregon, and Washington, DC. All profits are dedicated to the conservation and restoration of nature.

PV Components:

Direct Power & Water Corp. • www.power-fab.com • PV mounts

Discover • www.discover-energy.com • Batteries

Fronius • www.fronius-usa.com • Inverter

Mitsubishi • www.mitsubishielectricsolar.com • PV modules

OutBack Power • www.outbackpower.com • Inverters & controller

Resources:

3Degrees Energy • www.3degreesinc.com • REC broker

Bonneville Environmental Foundation • www.b-e-f.org

Cascade Solar Consulting • www.cascadesolar.com • PV system installer

Database of State Incentives for Renewables & Efficiency • www.dsireusa.org • Incentive information

Tax Incentives Assistance Project • www.energytaxincentives.org • Federal & state government solar incentives

Related Reading:

"Grid-Tied Solar in Small-Town, USA," Andy Kerr, *HP101*

"Mixing Business & Pleasure," Andy Kerr, *HP117*

"Making PV Pay: It's Just Good Business Sense," Andy Kerr, *HP117*

"Doing Well While Doing Good," Andy Kerr, *HP86*

"Financial Payback on Residential California Solar Electric Systems After the State Rebates Are Gone," Andrew J. Black. Presented at Solar 2004, Portland, Oregon, July 2004 for the American Solar Energy Society.

"Evidence of Rational Market Valuations for Home Energy Efficiency." Rick Neven and Gregory Watson. *The Appraisal Journal.* October 1998.

"More Evidence of Rational Market Values for Home Energy Efficiency." Rick Neven, Christopher Bender and Heather Garzan. *The Appraisal Journal.* October 1999.

SHW RETROFIT

by John Vastyan
photos by Holly Noel

The first of this two-part series focused on the Wenger home's "regreening," including insulation upgrades and a geothermal-to-radiant heating system. In this part, the Wengers are still on the efficiency path—this time integrating solar-thermal equipment for additional space and water heating.

Few would consider Pennsylvania the "sunshine state." Compared with Florida and the Southwest, it certainly gets less solar radiation—but, surprisingly, it gets more than enough to make solar viable. In most areas of the United States, there's sufficient solar energy to offset a significant portion of your electricity and water-heating bills.

"Give a few solar collectors 6 or 7 hours of southern exposure and amazing things can happen, even in our state," says Dave Yates, president of York, Pennsylvania-based FW Behler, a contracting firm that specializes in energy-efficient mechanical systems.

In 2008, Yates's firm was tapped by Travis and Rachel Wenger to give their 2,400-square-foot, three-bedroom log home a substantial mechanical makeover. As the Wengers embarked on a whole-house remodel—replacing the plumbing, mechanical and electrical systems—Yates's task was to install geothermal systems for radiant heating and air-conditioning (see "Geo to Radiant Retrofit" in *HP134*).

The Oventrop flat-plate collector is installed on the house's roof (the detached garage is in the background).

After those mechanical systems were installed, Yates turned his attention to the solar thermal solution. "We saved the best part for last," says Travis. In the fall of 2009, Yates's crew arrived at the Wenger house with a truckload of solar gear that would soon meet a large part of the home's domestic water-heating load. Surplus production would be diverted to the home's geo-to-radiant heat system.

Yates makes the roof penetrations for the thermal lines.

The sweating of the thermal line-sets begins.

Inserting the evacuated tubes into the header.

Clipping the bottom of the tubes into the lower end of the rack.

The Wengers' house on their 16-acre mountainside property is their indoor refuge during the six-month heating season. And, from April through September, when sunshine is at its best, they use the home as base camp for "waves of visitors" who come to hike, bike, and enjoy water sports.

"Having enough hot water for showers, baths, and washing clothes and dishes was going to be a real challenge with eight to 12 people in the house," says Rachel. "When we brought this to Dave Yates's attention, he offered the concept of tying in solar water heating. That struck us as a great idea."

Fortunately, the Wengers and Yates had this conversation early on, when Yates was designing the home's new heating system. Domestic hot water (DHW) sizing was calculated using the solar thermal resource combined with second-stage electric heating elements that would kick on as required to aid in recovery. Yates used his Solar Pathfinder, a solar siting tool, to determine the viability and yearly potential for solar domestic hot water to supplement the home's hot-water supply.

Yates calculated that a 4- by 8-foot flat-plate collector and one 16-tube evacuated-tube collector would exceed the Wengers' domestic water-heating needs during the summer and provide approximately 30% of the DHW load during poorer winter conditions.

"Flat-plate collectors lose some heat (10%) to the surrounding air," says Yates, "and the hotter the fluid, the faster the Btu go airborne. For this system to operate at peak efficiency, the flat-plate collectors handle the first stage, receiving the coolest water first.

"Vacuum tubes lose very little heat to the surrounding air," says Yates, "so we're gaining in efficiency by sending the warmed water from the flat-plate collector to the evacuated-tube collector. [Marrying the two types of collectors] also provides better economy because flat plates cost less than the equivalent number of evacuated tubes. Basically, the Wengers' 'hybrid' two-collector system is equal to three 4-by-8 flat-plate collectors, but will have higher performance. Although it's not done often—in fact, it's seldom tried— the Wengers were good

Tech Specs

Overview

System type: Closed-loop glycol solar hot water

Location: Central Pennsylvania

Solar resource: 4.4 average daily peak sun-hours

Ave. Monthly Production: 820,161 Btu

Hot water produced annually: 83%

Equipment

Collectors: Oventrop OV-5 16-tube collector; Oventrop OVF-32 flat-plate collector

Collector installation: Roof-mounted on south-facing roof at 45° (flat-plate collector) and parallel to roof plane (evacuated-tube collector)

Heat-transfer fluid: Glycol-water mixture

Circulation pump: Regusol 169-80-65

Pump controller: Regusol 130 pumping station

Storage

Tanks: Bradford White, 120 gal.

Heat exchanger: Bradford White

Backup DHW: Bradford White, 80 gal.

System Performance Metering

Thermometer: Regusol 169-80-65

sports and willing to let me experiment, and Oventrop's Peter Biondo was instrumental in getting this design used."

Because the Wengers would be absent from the property for extended times, Yates looked into integrating excess solar heat-energy into the home's radiant heating system once the DHW target-storage temperature was satisfied. Fortunately, there was an off-the-shelf solution. Watts Radiant builds a control panel—the Source-Select—exactly for this purpose. Designed to easily integrate multiple heat sources, typically a renewable source with backup, it was ideal for the Wengers' system. When their water heater reaches a set temperature, the control panel senses the additional heat from the solar thermal system and activates the pumps to redirect the solar-heated water into the home's hydronic radiant heating system.

Sunny Side Specifics

The two solar thermal collectors were mounted on the south-facing roof. When the Oventrop control unit senses the collectors are heating up, it circulates a glycol solution through the collectors. The heat-transfer fluid circulates through insulated lines that run to the basement where it enters the lower heat exchanger in a 120-gallon, twin-coil Bradford White indirect water heater. The separate, upper stainless steel coil is the business end of the unit—where it preheats water coming into the 80-gallon Bradford White electric water heater beside it.

"Bringing incoming ground water up to 120°F is where the lion's share of Btu are consumed in heating domestic water," says Yates. "By preheating it with the sun, everyone wins." The Wengers save energy and, in the long term, money on their utility bills.

Capturing Another Renewable Resource

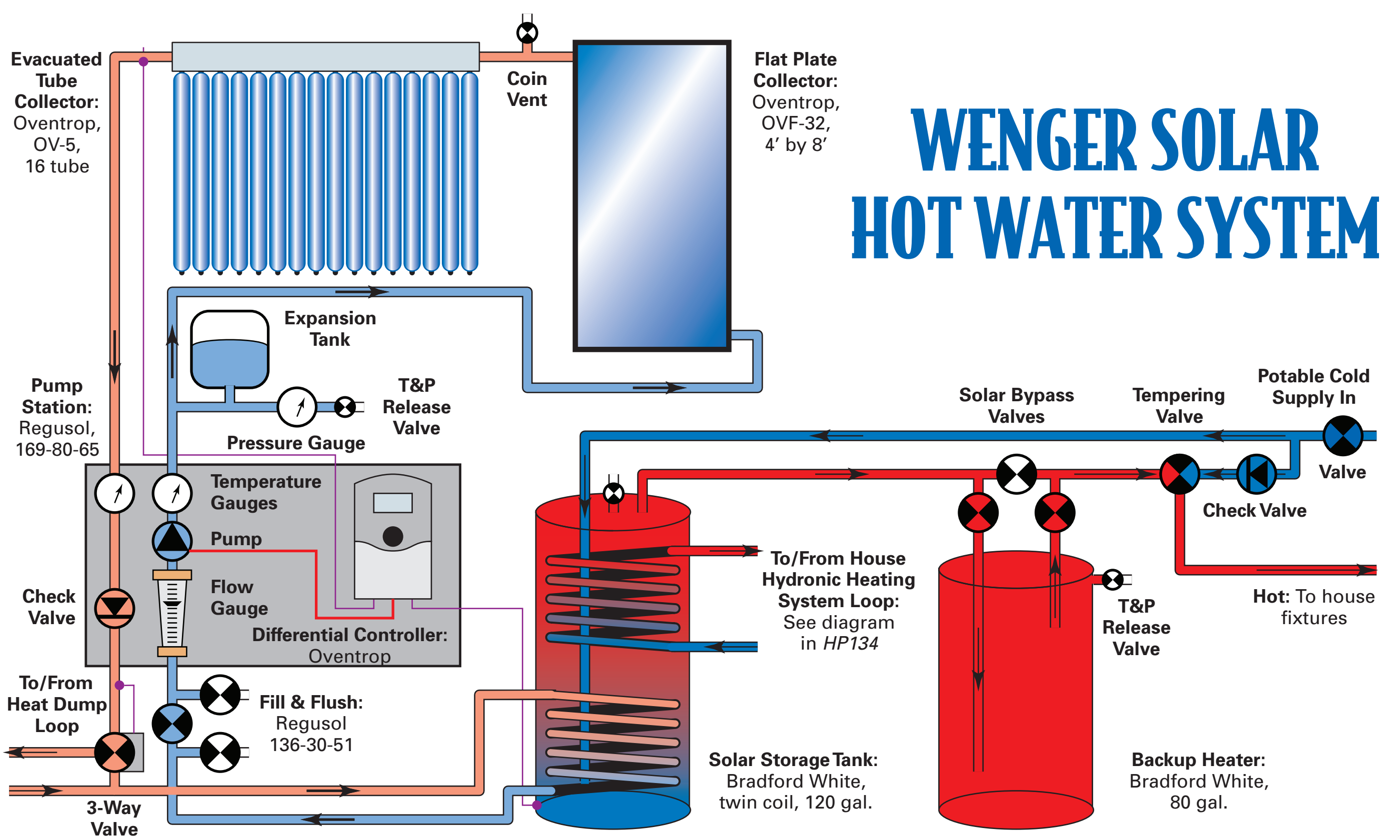
Near the garage, the Wengers sunk a 1,700-gallon rainwater storage tank. Garage downspouts go underground to supply it. Though the water could have been diverted to the toilets for greywater flushing, the Wengers use it all to irrigate the 125 trees they planted.

"It was ideal, because last summer was relatively dry," says Travis Wenger. "We would have put a huge strain on the pump and the well to provide water for all of the trees. But the few heavy rainfalls we had easily filled the catchment tank, giving us all the water we needed to sustain them. In 10 years or so, we'll have our own made-to-order forest."

Getting the tank in the ground was a bigger task than they anticipated, but local excavator Denny Runk made easy sport of it. With a backhoe, Runk dug a 10-foot-wide by 12-foot-deep crater and lowered the tank onto a two-foot bed of sand. He then filled the hole around the tank, while Travis and Rachel tamped sand and stone dust tightly around it with each new bucket load. It took about 30 tons of sand and stone dust to surround the tank with a protective cocoon. Then, the piping and wiring for the submersible pump were dug in.

The tank is now completely underground with only a frost-free faucet above ground. The Wengers simply connect a line or two of hose to the faucet and water with the captured cloudbursts.

Wenger Solar Hot Water System



Storage tanks and pump-stack/controller.

Yates had previously surveyed the location during earlier trips to the Wenger property, noting that the south-facing rooftop received solar radiation from 8 or 9 a.m. until late in the afternoon. The Solar Pathfinder confirmed that the solar window was unobstructed by surrounding woodlands, although a chimney's shadow would need to be avoided.

For enhanced winter production, Yates chose to tilt the flat panel at 45° to favor solar harvesting in winter. The evacuated-tube collector was installed parallel with the roofline—at 25 degrees—for optimal year-round production. Snow melts rapidly in the winter on the Wengers' south-facing roof, so that wasn't a concern and future plans call for tilting both at 39° to further experiment with achieving better performance.

A 60-foot-long coil of thick-walled, soft copper tubing, buried in a large hole behind the house and entombed in well-packed sand, serves as a summer heat sink "To prevent the system from overheating, we needed a dump zone," explains Scott Barnett, a technician at FW Behler. "If the Wengers weren't home and no solar-heated water was being used, especially on a summer day with maximum solar heat, we needed to ensure that excess heat had a place to go. And we thought the best place to divert it was to earth."

Homeowners Travis and Rachel enjoy the great outdoors at their rural retreat.

If the solar tank hits 120°F, and the electric water heater also has met its set-point of 140°F (to control bacteria), a control diverts the heated glycol/water mixture into the heat-dump coil to disburse the excess heat into the sand around it.

Yates says that, even on a cloudy day, Travis and Rachel's system can expect a solar gain between 2,000 and 10,000 Btu. "For maximum, mid-summer gain, the system is estimated to receive 60,000 to 80,000 Btu of solar-heated energy each day—enough to heat 148 gallons from 55°F to 120°F. That's a lot of free energy."

"The Wengers now have one of the best solutions for efficient heating, and will probably see a 60% to 80% drop in energy expenses this year compared to their first year in the home," says Yates. "The carbon footprint got a lot smaller, but they've added tremendously to the size of their comfort zone."

Access

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Winning Ways

2009 Solar Decathlon

by David Brearley
photos courtesy Stefano Paltera, U.S. Department of Energy Solar Decathlon

Students with Team Germany fasten the last SunPower PV module in their 12 kW rooftop array.

Following the U.S. Department of Energy's initial request for proposals in 2007, 20 college teams were selected to compete in the 2009 Solar Decathlon. The teams came from across the United States, as well as from Canada, Spain, and Germany. Each team received $100,000 in seed money from the DOE. Students fundraised the rest of the project budget. In some cases, they raised an additional $500,000 or more.

Each Solar Decathlon team must design and build an 800-square-foot home that comes as close as possible to using 100% solar for all of its energy inputs: electricity, water heating, space heating, and cooling. They must then transport their home to the National Mall in Washington, D.C. Once there, the team members rebuild the home, install the energy systems, and put the decks and landscaping together. Then the homes host some 120,000 Mall visitors over the course of the nine-day, 10-category competition.

This is the fourth U.S. Solar Decathlon. First held in 2002, the DOE has hosted the event biennially since 2005. The most recent competition was held October 8 to 18, 2009. During the competition, staff from the National Renewable Energy Laboratory monitor and log a variety of sensors in each home: indoor temperature and humidity; refrigerator and freezer temperatures; dishwasher water temperature; appliance energy consumption and run times; PV system performance parameters; and many more. To score points, the homes must do more work with less energy. Things like surplus energy exported to the utility grid are measured to determine points earned. Meanwhile, panels of construction-industry judges visit each home to make subjective determinations about the quality of different aspects of the projects.

Competition in the Decathlon provides phenomenal real-world experience for both students and faculty. By the time the competition starts, everyone involved has already gained valuable knowledge and experience—but only one team can win the gold. Here is a breakdown of how the winner of the 2009 U.S. Solar Decathlon was ultimately determined.

Subjective Contest Winners

There are five subjective contests in the Decathlon:

- Architecture
- Communications
- Engineering
- Lighting Design
- Market Viability

Each contest has its own jury, consisting of three industry leaders and subject matter experts. For example, Sarah

Susanka, author of the popular *Not So Big House* book series, was one of three architecture contest jurors. The juries also included professional engineers, construction project managers, lighting designers, LEED Accredited Professionals (a certification from the U.S. Green Building Council), marketing professionals, business owners, university instructors, and even a former solar "decathlete." In addition to judging the homes, jurors also reviewed the teams' project plans and manuals.

Team California's Refract House, with its articulated building footprint, a single-plane PV array, and inside-outside connections, scored high in the Architecture contest.

Winners

Here are the subjective contest winners and a brief overview of their strategies for success:

Architecture. This jury evaluates elements, such as materials used, building scale and proportion, and indoor and outdoor connections. Another consideration is holistic design: ease of entry, circulation, and strategies for integrating solar technologies. Last but not least, the jury must try and quantify the team's inspiration. In this category, they look for surprises, such as unusual uses of conventional materials or the use of extraordinary materials.

Team California, a collaboration between Santa Clara University and the California College of the Arts, placed first in the Architecture contest, scoring 98 out of a possible 100 points. Because the Architecture results are announced on the fourth day of scoring, this established Team California as an early favorite to win the overall competition. After all, in the 2007 Decathlon, Santa Clara University finished in third place overall after only placing eighteenth in Architecture. The design input from the California College of the Arts assured that there was no slow start for the team in 2009.

The Refract House from Team California impressed the judges on many levels. First, their out-of-the-box thinking was applauded. Because Solar Decathlon homes have to travel to and from the event—in some cases, over thousands of miles—some competition homes are designed to fit on a tractor-trailer chassis. Team California had a different response, bending and articulating that long rectangular form.

Team California achieved this effect by using three building modules, which had to be individually craned into position. The modules are oriented as if to form three sides of an irregular hexagon, opening to the south, with the center filled by a generous porch. Each module corresponds with a different activity: entertaining, cooking, or sleeping. The team describes the arcing form of the foundation as mirroring the sun's path in the sky. It also creates three distinct microclimates in the house. Because the orientation of each room differs, the living room, kitchen, and bedroom all enjoy different views and unique daylighting qualities. All three building modules have views across a central courtyard, leading one judge to comment that the interior and exterior of the Refract House appear as one.

Another unique feature of the Refract House is that its PV modules are integrated into a single plane across all three building modules, a design judges preferred over the more typical flat-roof profile of saw-toothed rows of PV modules. Finally, Team California's design came with some architectural surprises. The porch off the living room, for example, looks out over a shallow reflection pond filled with captured rainwater.

Communications. One of the most important roles of the Solar Decathlon is building public awareness about net zero-energy buildings, distributed renewable energy, energy efficiency, and the emerging "green jobs" economy. Successful communications strategies are key to making the event a success in this regard. A jury of public relations experts and Web site developers determines the winner of the Communications contest.

The communications strategies take many forms: signage, pamphlets, tour guides, and the team's Web site. They work together to elucidate design approaches, technologies, and products, as well as brand the homes or point to additional learning resources. Communications materials are also important because visitors may spend a half hour or more waiting in line to visit a Solar Decathlon home—more time than they will spend inside of the home. Therefore, signs placed along the ramps and decks leading into the homes are vital to introducing project features and important concepts.

Once inside a Solar Decathlon home, team members are on site to explain aspects of the project in detail, answer any

Conventional BP and Sanyo bifacial PV modules are integrated into the roof and façade of the University of Minnesota's ICON Solar House.

questions, and keep visitors moving efficiently through the home. Pamphlets or booklets are provided to visitors with educational and inspirational take-away materials. The Web site is also critically important. Teams use these sites for everything from raising funds and public awareness to brand building and live blogging. The Web site also serves as the project archive after the Decathlon is over.

Impressing jurors with their comprehensive and easy-to-navigate Web site, attractive and informative signage, well-written printed materials, and friendly and knowledgeable tour guides, Team California won the Communications contest, receiving 69.75 points out of a possible 75 in the event.

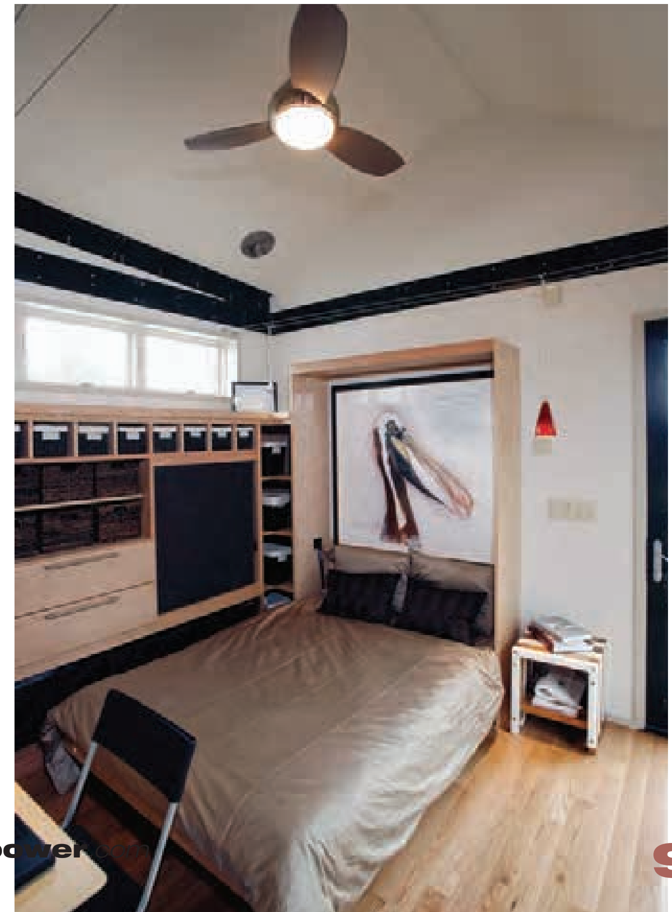
Engineering. Solar Decathlon homes employ a variety of active renewable energy systems, such as PV and solar water heating. Passive energy strategies include window selection and orientation, wall and ceiling insulation, and thermal mass. A jury of professional engineers assesses these systems and design decisions for functionality, efficiency, innovation, and reliability.

The University of Minnesota won the Engineering contest, scoring 96 out of 100 points with its ICON Solar House. Minnesota's main PV array, 5.7 kW of BP 190 W modules, is integrated into the building over an EPDM roofing membrane and serves as roof cladding. Two additional subarrays of

Direct and ambient daylighting strategies helped the University of Minnesota win the Lighting Design contest.

The Market Viability judges liked the transitional porch and spacious kitchen of the University of Louisiana at Lafayette's BeauSoleil home.

The general public voted for the BeauSoleil House as their favorite solar home on the National Mall.



Sanyo HIT Double 190-watt modules, which produce energy from both faces of the module, are integrated into the patio overhang and the south façade. The resulting 7.8 kW PV array was the twelfth largest in the competition.

For space heating, the house first calls on passive solar gain through triple-pane, argon-filled, low-emissivity windows on the south wall. This is combined with R-50 insulated walls and an R-70 insulated ceiling. When passive strategies are insufficient, water heated by six Veissmann flat-plate solar collectors heats the space hydronically, via PEX tubing in the floor.

The solar thermal system was optimized both for the competition and for Minnesota's cold winters, which would result in surplus hot water in summertime, a common problem faced by solar thermal system designers. But the Minnesota team had a bright idea: Why not put that thermal energy to work?

The team designed a desiccant system that uses solar thermal heat to extract humidity from the home in the summer—effectively using heat to cool the house. On the hottest days, a minisplit heat pump is used to condition air further. Because it does not have to dehumidify, the air conditioner runs more efficiently.

Lighting Design. Distinguished lighting designers were the jurors tasked with evaluating both the electric lighting and daylighting quality of the homes. Ease of operation was a consideration, and the lighting system had to aesthetically accommodate a wide variety of activities—reading, working, entertaining, or relaxing—across all four seasons. Finally, building integration and energy efficiency were scored.

The University of Minnesota also took first place in the Lighting Design contest. Using thoughtful daylighting strategies and energy-efficient artificial lighting, the ICON Solar House earned 72 out of 75 possible points. The team balanced the placement of windows by using sun-path and energy modeling software. Even on a rainy day in October, north-facing clerestory windows, along with the open floor plan, create a light-filled home that feels spacious.

Recognizing that people gravitate to natural light, especially in northern climates, the Minnesota team intentionally sought to coordinate daily activities with natural light. For example, morning light fills the kitchen, located on the east side of the house. SageGlass electrochromic windows can be darkly tinted at the flip of a switch to modulate visible light transmission and solar heat gain. Voltage applied to ceramic coatings on the window causes the materials' ions to migrate and the window to darken, while still maintaining a view. Elsewhere, fixed, exterior louvers are used to manage daylighting.

Beneath its recycled barn-wood cladding, the University of Illinois' Gable Home features super-insulated walls and ceilings.

In addition to the Home Entertainment contest, the Gable Home also won the Appliances and Hot Water contests.

Electric lighting in the ICON Solar House is accomplished using 97 separate LED lights, as well as one compact fluorescent and one T5 fluorescent tube. Attractive task lighting punctuates ambient lighting on work surfaces and architectural elements. The fixtures are operable from standard switches, as well as from the home's central computer-controlled system. Both the interior and the exterior of the home are dramatically and generously lit to meet the contest's criteria for ample lighting throughout, but at an average of just 5 W per light.

Market Viability. Professionals from the residential construction industry evaluate the Market Viability contest, considering a home's livability, ease of construction, and marketability. They evaluate how well the home functions, how complete the construction plans are, and how attractive the home is to its target audience. Each team defines its own target market—for example, retired couples on a fixed income or a double-income family with no kids.

The BeauSoleil Home from the University of Louisiana at Lafayette won the Market Viability contest with 97 points out of a possible 100. Due to the cost for the home (about $250,000, or $312 per square foot), the team defined its target market as "Prosperous Empty Nesters" with a household income of $120,000 or more per year. But the team's intent is to commercialize a more affordable version of the home. According to the team's project manual, "Based on producing 100 homes, we have established a budget of $125,000 for the mass-produced model of the BeauSoleil Home," making the home affordable to a family that makes $50,000 annually.

Phase-change materials inside the walls and ceiling of the Team Germany house moderate temperature swings—and enabled the team to win the Comfort Zone contest.

With a Louisiana lifestyle in mind, the BeauSoleil home is designed to accommodate entertaining, socializing, and cooking. A transitional porch at the center of the home separates the kitchen from the bedroom and bathroom. This porch is a modern interpretation of the dogtrot, a covered breezeway common in Cajun architecture. It features an engineered folding-and-sliding glass wall and door system from NanaWall that allows the porch to be configured as either interior or exterior space. When the movable glass panels are stowed away, the porch is open to the south. Rolling screens can be pulled down to make the space insect-proof. Low-maintenance, long-lasting materials are used throughout the home, such as moisture-resistant cypress siding and a standing-seam metal roof.

The judges' choice in the Market Viability contest was roundly seconded by paper and online balloting, as the BeauSoleil home also won the People's Choice award.

Objective Contest Winners

There are also five objective contests in the Solar Decathlon:

- Appliances
- Comfort Zone
- Home Entertainment
- Water Heating
- Net Metering

Of these, the greatest importance is placed on net metering, which is worth a maximum of 150 points. The objective contests are all individually measured using scientific-grade equipment. Representatives from the National Renewable Energy Laboratory impartially record the results.

Appliances. Points are earned in this event for refrigerating and freezing food, washing and drying laundry, and running the dishwasher. Teams score the maximum number of points by using the least amount of energy, while imitating appliance use in the average U.S. home. This requires maintaining specific refrigerator and freezer temperatures, washing 10 loads of laundry during the week of the contest, and running the required dishwasher five times.

Scoring 95.53 points out of 100, the University of Illinois' Gable Home captured first place in the Appliance category. According to student project manager Joe Simon, "Energy-efficient appliances were key to maximizing the performance of the house. We kept costs low by focusing on energy efficiency rather than energy production. As a result, our solar plant capacity was only the eleventh largest."

To maximize energy efficiency, the University of Illinois team specified a Sun Frost RF12 refrigerator/freezer, an LG combination washer/dryer, and a Fisher & Paykel DishDrawer dishwasher.

Comfort Zone. To score points in the Comfort Zone category, teams must maintain the temperature and humidity inside

Team Germany's 17.8 kW PV system—the largest in the competition—helped ensure another Solar Decathlon win.

their homes within narrow ranges: between 72 and 76°F, and between 40 and 55% relative humidity.

By scoring 92 out of 100 points, Team Germany (Technische Universität Darmstadt) won the Comfort Zone contest. Defending its first-place finish in the 2007 Solar Decathlon, Team Germany built its 2009 entry to the German "Passivhaus" standard. This means that the home should use 90% less energy than a comparably sized conventional home. In Germany, the bulk of a home's energy demand is dedicated to space heating.

Team Germany focused on high insulation values and airtightness. For the competition venue, however, the team was particularly concerned about the possibility of overheating, which was an issue during the 2007 Solar Decathlon. After energy modeling for October in Washington, DC, the home's windows were reduced in size and an automatic window shading system was designed. Additionally, Knauf PCM Smartboard, a gypsum board with latent heat storage, was installed on the walls and in the ceiling. The phase-change materials embedded in the drywall provide thermal mass, stabilizing interior temperature fluctuations.

Home Entertainment. The activities that are quantified for the Home Entertainment contest include: cooking, watching movies, computer use, and illuminating the home's exterior and interior. According to the contest guidelines, the goal of this event is to judge whether solar-powered houses have what it takes to be a home. As such, they must accommodate activities that we all enjoy, but do so on a streamlined energy budget. Scores are based on how much energy is consumed supporting these tasks. Also, teams must host two dinner parties for their neighbors, with the guests scoring the experience.

Building on its strong showing in the Appliance category, the Gable Home from the University of Illinois also won the Home Entertainment contest. It scored 92.62 out of a possible 100 points. The team used LED lighting for the interior and exterior. The 55-inch Samsung HL series television uses digital light processing technology and has one of the best power-to-screen-size ratio of any television on the market. The team also installed high-quality, low-energy speakers to complete the home theater experience.

For cooking, the University of Illinois team chose a Diva DDP-2 12-inch induction cooktop. Unlike gas stoves that are 50% efficient in transferring heat, induction stoves are more than 90% efficient. An efficient GE Monogram oven and microwave combination unit is also used in the kitchen of the Gable Home. All of the appliances are Energy Star-qualified products.

Water Heating. To prove that contest homes can deliver all the hot water that a typical U.S. household needs, the Hot Water contest requires that teams complete several daily water draws, where 15 gallons of 110°F water must be delivered in 10 minutes or less. A water temperature of 120°F is required for the dishwashers.

2009 Solar Decathlon Contest Results

Team	Web Site	Appliances	Architecture	Communications	Comfort Zone	Engineering
Team Germany	www.solardecathlon2009.de	89.05	94.00	53.25	92.01	91.00
Illinois	www.solardecathlon.uiuc.edu	93.54	77.00	60.75	92.65	88.00
Team California	www.refracthouse.com	92.58	98.00	69.75	63.09	95.00
Team Ontario/BC	www.team-north.com	89.21	91.00	66.75	91.34	79.00
Minnesota	www.solardecathlon.umn.edu	91.17	81.00	58.50	78.34	96.00
Team Alberta	www.solabode.ca	62.15	80.00	62.25	79.63	77.00
Cornell	www.cusd.cornell.edu	56.18	70.00	66.75	64.45	81.00
Rice	www.ricesolardecathlon.org	51.31	95.00	64.50	67.08	84.00
Kentucky	www.uky.edu/solarhouse	70.12	71.00	51.75	64.89	77.00
Ohio State	www.solardecathlon.osu.edu	51.26	82.00	64.50	82.36	84.00
Team Missouri	http://solarhouse.mst.edu	64.78	64.00	60.75	50.78	72.00
Iowa State	www.solard.iastate.edu	43.21	61.00	66.00	66.64	88.00
Virginia Tech	www.solar.arch.vt.edu	42.85	94.00	56.25	71.82	88.00
Team Spain	www.solardecathlon.upm.es	63.94	72.00	55.50	54.04	84.00
Team Boston	www.livecurio.us	53.38	87.00	63.00	58.30	80.00
Penn State	www.naturalfusion.org	53.94	67.00	63.00	59.70	93.00
Puerto Rico	www.casasolar.uprrp.edu	63.98	74.00	42.00	70.19	85.00
Arizona	www.uasolardecathlon.com	69.67	86.00	45.00	49.29	87.00
Louisiana	www.beausoleilhome.org	78.32	78.00	52.50	72.08	79.00
Wisconsin	www4.uwm.edu/uwm_sd09/	62.23	64.00	48.75	62.88	67.00

* Overall scores reflect penalties, but individual scores do not. Therefore, the total score presented may not match the sum of contest scores.

Members of Team California give Secretary of Energy Steven Chu a tour of the Refract House.

The University of Illinois' Gable Home won the Hot Water competition with a perfect score of 100 points—and without using a solar thermal system. The Gable Home uses solar electricity to heat water—with a twist.

The team mated an electric air-source heat pump with a superinsulated Rheem electric water tank. The heat pump extracts heat from ambient air and transfers it to the water in the Rheem tank. The heat-pump also reduces the home's air-conditioning load via electronic dampers that can direct cold exhaust air into the home in the summer.

Using the Solar Decathlon as a Resource

Teams competing in the Decathlon come from all over, so there's likely a Solar Decathlon home in your region that you can study and learn from. Resources like plan sets and project manuals are available online. In some cases, competition homes are open for tours, back on campus or elsewhere. Here is how you can benefit from the teams' research and experience:

Climate-responsive design strategies. Each home takes into account passive heating and cooling, shading strategies, and insulation levels for its region. Learn about the precise green building strategies that are most appropriate in your area, whether that is the Far North, the Midwest, or the Deep South.

Project models & plan sets. Solar Decathlon project manuals include information about design evolution, energy modeling, and system selection. It is fascinating to learn how and why certain decisions were made. Understanding these design decisions can help guide your design and optimize your projects.

Detailed product lists. Every team publishes a complete list of products used in their home, including appliances, insulation, flooring, and solar equipment. These lists are great resources for homeowners looking to find the most efficient dishwasher or windows.

Home Entertainment	Hot Water	Lighting Design	Market Viability	Net Metering	Total*
87.04	95.20	69.75	91.00	150.00	908.30
92.63	100.00	70.50	86.00	137.24	897.30
92.18	95.00	68.25	92.00	100.24	863.09
71.36	94.25	69.00	89.00	109.91	849.82
87.65	88.35	72.00	91.00	100.53	838.54
86.45	79.05	65.25	81.00	100.13	769.41
85.76	85.65	65.25	89.00	100.19	764.24
48.10	85.00	63.00	93.00	100.25	750.24
74.92	77.70	57.00	84.00	104.77	732.15
60.49	62.25	57.75	91.00	101.32	729.93
70.75	85.00	65.25	87.00	100.71	719.53
64.05	71.35	63.00	92.00	101.37	714.61
47.87	56.65	65.25	90.00	100.94	704.63
65.87	33.00	60.00	80.00	109.22	669.57
52.91	78.50	64.50	87.00	44.01	665.60
70.95	63.65	69.75	87.00	0.00	626.00
61.41	75.00	66.00	85.00	0.00	617.57
65.14	73.25	60.00	79.00	0.00	610.34
76.03	7.20	63.75	97.00	0.00	603.88
63.72	45.00	60.00	76.00	0.00	542.07

Net Metering. With 150 points at stake, the Net Metering contest determined the ultimate winner of the 2009 Solar Decathlon. It is notable that the three previous Decathlons had required teams to design 100% stand-alone homes, complete with large-capacity battery banks. This required more complex PV systems, greater capital outlay, and perpetuated the public's perception that solar electricity was prohibitively expensive and only for people without access to the utility grid. To reflect more typical living conditions, the competition now requires teams to use batteryless grid-tied systems with bidirectional kWh meters that measure net energy produced or consumed. Net metering is the norm in the United States and also is now the norm for the Solar Decathlon.

Teams receive 100 Net Metering points for offsetting 100% of their electricity needs with their PV systems.

Supersized PV: Playing to Win

Even though the Decathlon homes are ultra-efficient and small (each is less than 800 square feet), their solar power plant capacities are quite large. According to the DOE, the average grid-connected PV capacity at the 2009 Solar Decathlon was 9 kW—enough to generate more than 10,000 kWh annually in Washington, DC. Ironically, this is roughly the energy consumption of an average, *inefficient* U.S. residence.

Further, 16 of the 2009 entries included solar thermal systems, meaning that the total solar power capacity for the homes was even larger. The average solar thermal capacity at this event was 3.2 kW. So what gives?

Although energy inputs this large aren't necessary for real-world operation of these super-efficient homes, winning the Solar Decathlon is a little more complicated. Here, simply net-zeroing annually is not enough. Systems have only nine days to meet or exceed the house's energy demands—despite the weather, which, in October, can be cloudy and rainy. So at the Decathlon, having an oversized system helps secure a win.

Over the years, competition rules have invariably favored the team with the largest PV-generating capacity. This year, for example, bonus points were available for surplus energy generation. With the largest PV array capacity at the event, 17.8 kW, Team Germany won the overall competition largely due to its perfect score in Net Metering. In years past, the ability to drive an electric vehicle the furthest provided a similar incentive to oversize PV arrays. The University of Colorado similarly won the inaugural Solar Decathlon in 2002 thanks in part to its 7.7 kW PV array, again the largest at the event.

It is no accident that the average PV array capacity at the Solar Decathlon has increased in every competition, up from 5.2 kW in 2002 to 9 kW in 2009. As long as competition rules favor supersized PV arrays, teams playing to win will continue to design larger and larger PV systems. This is an unfortunate distortion of the competition that diminishes the more cost-effective role of energy efficiency in net-zero energy home design and construction.

Up to 50 additional points are available for surplus energy generation. The team that generates the most surplus energy receives those 50 points; other teams with excess energy generation are scored proportionally to the energy leader.

Team Germany won the Net Metering contest with 12 kW of Sunpower crystalline-modules covering the roof and 5.8 kW of Würth Solar thin-film modules distributed across three facades as cladding. While the thin-film modules are less efficient and not ideally oriented to the sun, they are also better at harvesting energy in low-light conditions. There were several rainy days during the competition when the ability to harvest energy in low-light conditions was perhaps critical to success.

The combined PV generating capacity for Team Germany's entry was 17.8 kW, making it the largest solar power plant of the Decathlon homes. The average PV system capacity at the event was approximately 9 kW. By generating the greatest energy surplus over the competition week, Team Germany won the Net Metering contest with a perfect score of 150 points.

Final Standings

There are a total of 1,000 points possible in the Solar Decathlon. Announcements and recording of subjective contest results are staggered across the event, but those scores are recorded in full on the day they are announced. Objective contest scores, on the other hand, accrue continuously over the course of the event. The end result is that tracking team scores is often dramatic and exciting, even for non-contestants.

On the final day of scoring, it became clear that Team Germany had successfully defended its 2007 victory. With the strongest showing in Net Metering, they leapt over the University of Illinois and into first place. The University of Illinois, however, had only climbed atop the leader board on the eighth day of the contest. Performing well in the objective events that emphasized energy efficiency, Illinois had slowly closed the gap on first place, finally taking the lead on the penultimate day. The team that spent the most time in first place was Team California. They took the lead on the fifth day, after the Communications and Architecture results were announced, and held that lead for several days. In the final standings, their Refract House finished third overall, matching Santa Clara University's finish in 2007.

The two other teams that won individual contests finished quite disparately. The ICON Solar House from the University of Minnesota, which won both Engineering and Lighting Design, finished in fifth place overall. It came in just behind one of the two Canadian entries, the clean, modernist North House from Team Ontario/British Columbia. The BeauSoleil House from the University of Louisiana at Lafayette was the crowd favorite, but finished second-to-last, in nineteenth place. Winning the hearts and minds of the general public, however, is the best imaginable outcome of the Solar Decathlon. In that category, the BeauSoleil House had its good day in the sun.

Access

David Brearley (david.brearley@solarprofessional.com), *SolarPro* Senior Technical Editor, has attended three consecutive Solar Decathlons and plans to go back for more in 2011.

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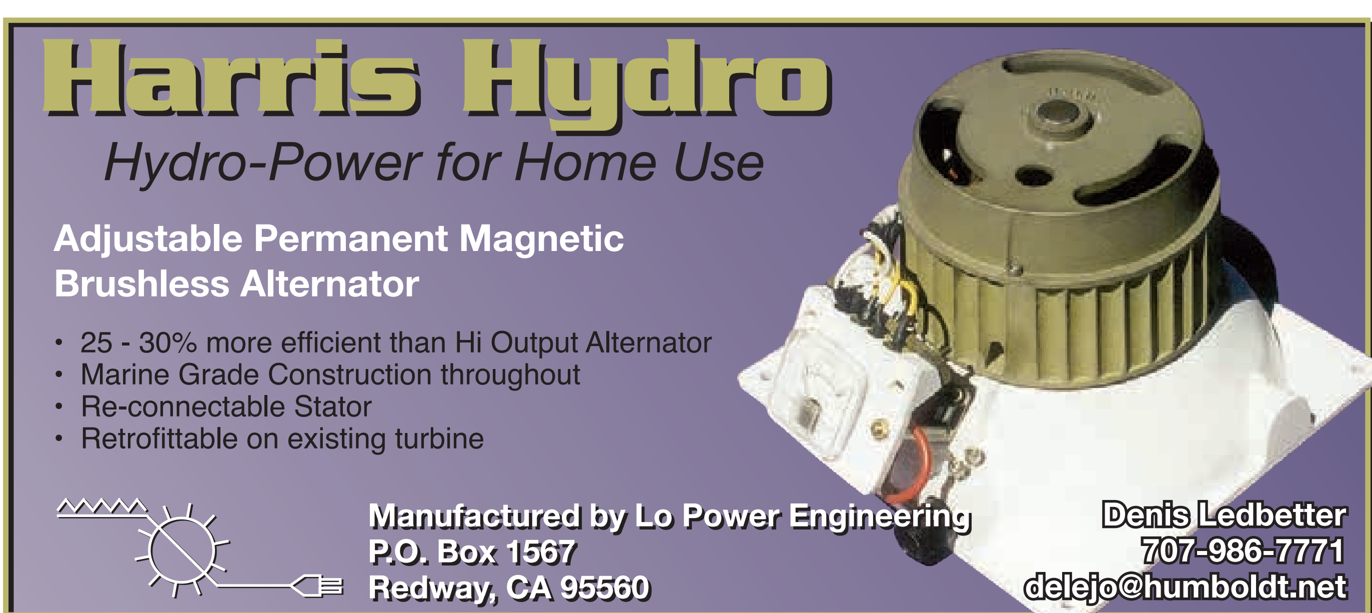
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wind-electric

SYSTEM MAINTENANCE

by Roy Butler & Ian Woofenden

If it's human-made and has moving parts, it needs maintenance. It doesn't matter if it's a spinning engine, a spinning wheel, or a spinning wind generator. You can't run a car for years—or even months—without maintenance and expect it to last long. And it's no different with a wind generator.

Veteran wind energy expert Mick Sagrillo says that the "average home-sized wind turbine will put on as many 'miles' in four months as the average car does in 100,000 miles." And regular maintenance is crucial for the survival, safety, and energy production of a wind-electric system. Once a year is a minimum for inspection and maintenance, and twice a year is usually better, especially if you have a good wind resource or experience frequent high winds or turbulence. Although some wind generator manufacturers say you can do a turbine and tower inspection with binoculars, we strongly recommend a more up-close approach: a hands-on, bottom-to-top, comprehensive annual inspection.


Courtesy Roy Butler

"If it's human-made and has moving parts, it needs maintenance."

Most modern wind generators do not have parts that need to be routinely replaced, like the brushes or bearings of older machines. So routine maintenance is primarily focused on inspection of the whole machine, cleaning, and tightening hardware. The spinning turbine and wind forces acting on a tower can cause vibration, which can loosen or damage hardware, turnbuckles, and other tower and turbine components. These are the types of things to watch for during an inspection.

Get ready first (see "Maintenance Gear" sidebar), and prepare all the climbing gear, tools, supplies, and spare parts you may need for the job. Use a good checklist and a digital camera to record any problems found. And have all the equipment manuals available—you'll be amazed at what you learn by reading them!

On the Ground: Electrical & Electronics

Before you climb the tower, there's a lot of work to be done on the ground. In addition to inspecting the tower (see below), we like to do maintenance and troubleshooting in the power room before we climb. Finding problems on the ground prior to climbing will help us know what to look for aloft.

Turbine to Inverter/Controller Wire Run

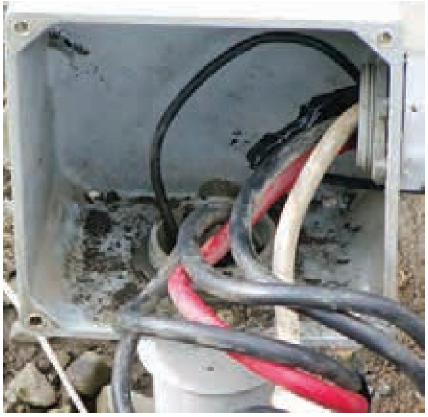
- Look for signs of damage on all conduit, wire runs, junction boxes, and conduit fittings, such as water intrusion, condensation, chew marks from critters, cracks, frost-heaving, and so on. Long conduit runs that were improperly installed can store several gallons of water, so be aware when opening junction boxes.
- Check wire terminals on all components (disconnects, junction boxes, inverter, controller) for proper tightness and signs of arcing or other degradation.
- Test all fuses and circuit breakers for electrical deterioration using the continuity tester on a multimeter and look

for physical deterioration. Cartridge fuses can deteriorate over time, especially in outdoor installations.

- Use a multimeter to check all surge arrestors. SOV- and MOV-type arrestors can only take so many voltage spikes before failing.
- Use a megohmmeter on wire runs to check for ground faults. Skinned or cracked wire insulation in underground conduit is one of the most common causes of ground faults. At the very least, system performance will suffer. Some older inverters can be damaged by ground faults. Worse yet, if the equipment grounding system is compromised as well, a shock hazard can result.
- While the turbine is operating, check for balanced three-phase output (when applicable). Allow for the fact that there will be variations in the wind speed and thus the voltage while you are moving the meter probes—you're looking for variations of 10% or more between phases. Test two or three times to rule out variations caused by changing wind speed.
- Perform other turbine-specific electrical tests per the manufacturer's recommendations. A good owner's manual will include testing protocols for the turbine electronics.

Electronics

- For grid-tied inverters, test the ability to disconnect when the grid goes down by turning off the inverter breaker and verifying "0 voltage" at the inverter output. After turning the grid breaker on, verify the 5-minute delay before the inverter reconnects to the grid.
- For battery-charging controllers, confirm that the charging set point programming is appropriate for the batteries. Verify the controller's ability to perform this function—by checking a voltmeter to make sure power is diverted when the high battery voltage set point is reached.
- When applicable, test the electrical integrity and operation of the turbine diversion loads.
- Make sure there is no flammable material near the diversion loads. Inspect any heat shields for physical damage and signs of overheating.



Inspecting junction and pull boxes, including all connections, is part of the routine maintenance needed on wind-electric systems. Note the water damage found in this junction box.

Courtesy Roy Butler

MAINTENANCE GEAR

Here are the primary things you may need for a maintenance check on a wind-electric system. For more information, see "Tools of the Wind-Electric Trade" in *HP124*.

- An assistant on the ground while you're climbing
- Climbing harness, lanyards, and fall-arrest device
- Two radios (be sure they're on the same channel!)
- Service line and pulleys
- Closeable tool bags
- Water bottle
- Lanyards and rope pieces for securing turbine and rotor
- Spotters and assistants for tilting a tower
- Electric, hydraulic, or Tirfor-type winch
- Various load-rated pulleys, cable, and shackles
- Digital camera
- Spud adjustable wrench with belt-mounted holster
- Insulated screwdrivers and pliers
- Sockets and wrenches (check manuals for appropriate sizes)
- Torque wrench (250 foot-pounds)
- Multimeter with probe leads and current clamp
- Megohmmeter
- Penetrating oil
- Grease gun and grease
- Spare hardware for turbine, tower, and guy cables
- Rags for blade cleaning
- Epoxy for blade repair
- Spare leading-edge tape, if appropriate
- Spare fuses
- Battery safety gear (goggles, rubber gloves, and baking soda)
- Anticorrosion paste for battery terminals and cable ends
- Distilled water
- Hydrometer
- Wire brushes
- Spare ground wire and clamps

- Clean dust or other obstructions from any cooling fans and vents. Heat dissipation is essential for proper electronics operation and has a direct effect on the equipment's life expectancy.

Batteries

Battery maintenance could be the subject of a complete article (see "Flooded Lead-Acid Battery Maintenance" in *HP98* for more information). Owners of battery-based systems will need to follow a basic maintenance procedure:

- Check all battery connections for tightness and clean corrosion from them; then grease or coat connections with an anticorrosion coating.
- Clean battery tops with water and a rag.
- Check electrolyte level and fill as needed with distilled water.
- Check settings on battery monitor.
- Check settings on charge controller(s).

On-the-Ground Tower Inspection

Safety First

Before climbing or lowering a tower, fully inspect all components accessible from the ground. Any serious problems must be corrected before climbing the tower.

Most home-scale wind installation companies receive several calls each year from system owners with turbines that have been orphaned by their original installer but still need inspection or repair. Although we apply the following procedures on all inspections, we always take a much harder look at an unknown installation.

Before You Climb

- Foundations: Check for excessive anchor movement. This may be the only indication of a failed or failing foundation system. Look for deterioration of the anchor rods or other attaching points, especially where they contact the concrete or the ground.
- All towers: Examine the overall appearance of the tower. Check that it is straight and plumb. Small discrepancies are OK, but a seriously out-of-plumb tower can be an indication of a more significant problem. At the very least, it could be dangerous to climb or tilt. Also check it for rust, since deep-rooted rust can affect the tower's structural integrity. Minor surface rust is to be expected. Probe the rusted area with a sturdy screwdriver or similar tool. Look for broken welds or structural components that are bent or missing. Bent or missing tower parts may be easy to spot, but cracked welds are not. Rust streaking around galvanized welded joints may be an indication of a cracked weld. If a safety-climb system such as a Lad-Saf is installed, check the cable and tensioner integrity. Fall-arrest systems should not be used for support at all until the entire fall arrest assembly is checked.
- Guyed towers: Inspect all hardware: turnbuckles, equalizer plates (which equalize the tension on each set of guy wires), cable clamps, etc., for deterioration, excessive movement, and tightness. Look for loose or missing lock nuts, Palnuts, and turnbuckle safety loops—these things can bring down a tower. Check guy wires for rust and broken or frayed strands. Pay close attention to the area where the cable passes around the thimble at the guy ends. This is a high-stress area, subject to vibration, susceptible to corrosion, and perhaps very difficult to see. Minor surface rust or the occasional missing guy cable strand may not present a major issue now, but bears watching. Once corrosion starts, it can accelerate quickly, especially in salt-air environments. Some tower grounding conductors are connected directly to the guy wires. Galvanic reaction from dissimilar metals may be causing corrosion inside the attaching hardware. Remove, inspect, and replace if needed.

The turnbuckle safety loops should never be allowed to rub against the guy cables. This photo shows an example of a rub point on the top of the lower turnbuckle. Friction and vibration will eventually damage this guy cable.

Courtesy Ian Woofenden

Inspect the tower base and all guy anchors—make sure there are no issues before climbing to inspect the tower and turbine.

Courtesy Roy Butler


Courtesy Roy Butler

A broken furling cable on a Bergey Excel means that there is no means of shutting it down. Regular inspections of braking and furling systems are crucial to safety.

Check for proper guy tension and adjust as needed. This varies between tower manufacturers, so follow the proper procedure for your tower. The tangential intercept method (using a bit of geometry and the sag of the cable) is often used for tilt-up towers; the oscillation method (using some math and a controlled shaking of the cable) is routinely used for fixed guyed lattice towers. Wind turbine installation manuals are great sources for this type of information.

- Freestanding towers: Inspect the hardware that secures the tower to the foundation. Look for signs of unusual movement around the hardware and leg flanges, such as misalignment, weathering patterns, or cocked bolts. If grout was used under the tower legs, check the drain-holes for blockage and clean as necessary. Moisture buildup inside hollow tower legs can lead to freeze damage and eventual tower collapse.

- Grounding: Never climb an ungrounded tower—look for proper grounding of the tower and guy wires. There are many different tower grounding methods, but they are beyond the scope of this article (for more information, see "Get Grounded: Renewable Energy System Grounding Basics" in *HP118*.) Again, review the tower manuals! Inspect the grounding wire and hardware. The most common problems found are loose and missing ground-rod clamps.

- Brake: Inspect and test the tower-mounted turbine disconnect and shorting brake. If applicable, check the furling or brake mechanism for proper operation. (This should not be done in a high wind.) Brake, short, or otherwise secure the turbine before ascending the tower.

On the Tower

Safety on towers requires knowing how to climb safely, and having the right equipment. There is no substitute for tower climbing experience, so if you're new at it, find a mentor and get some practice. Climb the fixed tower, lower a tilt-up tower or use a lift (see Access for articles on tower styles and tower safety).

Tower Mechanical

- Look for missing or loose bolts, nuts, and lock nuts. Carry several sizes and types of spare hardware with you so you can inspect and repair or replace hardware in the same visit.

- Check for proper torque. A good manual will have the manufacturer's recommended torque specifications and hardware sizes so you can throw the appropriate sockets and wrenches in your climber's tool bag. While the majority of tower hardware can be tightened with a torque wrench that goes up to 250 foot-pounds, some tower hardware may require 350 foot-pounds or higher—plan accordingly.

- Down-tower wiring. Check cable and conduit integrity and verify that it's properly secured. This will range from a Kellums-type hanger for jacketed multiconductor cable to various types of clamps for conduit, and even wire ties for flexible metallic-sheathed cable assemblies.

- Inspect tower-mounted data equipment, such as the boom, anemometer, and wind vane mounting hardware. Also check their wire integrity and tie-downs. The anemometer is another manufactured item that has moving parts. They do not last forever and may need to be replaced.

- On the way down, wire-brush rusted tower parts and apply cold-galvanizing spray or paint.

Wind Generator

- Turbine mechanical: Bearing problems may be difficult to spot, so learning to read the telltale signs of bearing failure—such as rust streaks—is essential. This is caused by moisture entering then exiting the bearing, which usually leaves a very distinctive, rust-colored residue behind. This is especially true for rotor bearings, where the streaks may be seen artfully arranged on one side of the blades.

- Where moisture has not been a factor, a fine black powder may be seen around the bearing race or on nearby surfaces. This is most often found in protected areas, such as the rear rotor and the yaw bearings inside the turbine nacelle. Grease/oil where it shouldn't be is a sure sign that sealed bearings are no longer sealed.

- Loose hardware can leave similar signs, where vibration and movement have worn away protective coatings and allowed oxidation to occur.

Courtesy Roy Butler (2)

Blade cracks and wear may call for repair, or they may be warnings of imminent blade failure, which can be catastrophic for machine and tower.

- Inspect turbine-to-tower mounting hardware and check for proper torque. Look for cracking or other signs of stress on the mainframe welds.
- Verify blade mounting integrity, including loose blades and loose or missing hardware.
- Check the blades for structural integrity: cracks, pits, erosion, leading edge wear, or damaged/missing leading edge tape. If excessive movement is found, egging of mounting holes or other damage may be present.
- Slowly spin the rotor, listening for unusual noise or feeling for resistance to turning, which can be caused by grit on the magnets, dry bearings, too much play, or magnets rubbing on the stator. Check for bearing slop by lifting upward on the rotor.
- Inspect all bearing and pivot points, which typically include rotor and yaw bearings, furling bearings or pivot, furling or brake assembly, and friction areas. On furling turbines, the tail pivot bushings are a high wear point, especially at turbulent wind sites. If the upper pivot bushing lets go, the tail can swing downward into the blades, destroying both.
- Inspect the governor assembly if applicable (for example, with Jacobs and Kestrel turbines). There are lots of moving parts in there that need loving attention!
- On turbines such as the Endurance S-250, check the brake pads for wear. Inspect the condition of the flexible hoses in the air brake system and check the color of the desiccant. The color changes as moisture is absorbed to indicate when replacement is needed.
- Check out the slip-ring and brush assembly. Look for pitting or roughness (signs of arcing), and uneven wear on slip rings. Brushes can jump track or track unevenly, causing excessive slip-ring and brush wear, arcing, and premature failure of the assembly. Inside this assembly is another place to look for black dust, metal shavings, or excessive grease from bearing failure, which can cause electrical problems by interfering with brush contact with the slip rings.

Telltale signs of damaged bearings—oil and rust streaks on the blades—call for immediate action.

Courtesy Ian Woofenden

- Inspect the turbine wire connections. Look for wear and loose terminals from vibration, evidence of arcing, and conductor insulation breakdown. Corrosion from moisture may be present yet unseen inside terminal blocks or other connectors.

Lubrication

- Some sealed bearings can be greased with a needle-type grease gun attachment. Any grease seal openings created during this process should be carefully and thoroughly sealed to keep out moisture. Small, handheld tubes of RTV sealant serve this purpose well.
- Where applicable, grease all fittings, and change gearbox oil (i.e., on Endurance and Jacobs turbines) according to manufacturer's recommendations.
- Watch where the oil goes when performing an oil change. An unplanned coating of oil on the tower will not make for a pleasant tower descent!

Maintain It—or Bury It

Don't believe anyone who says wind-electric systems can be maintenance free! The only time that holds true is if you leave all the components in their original boxes, and store them in a cool, dry place. Once you install and operate the system, it will need maintenance. In most cases, it will need periodic repair. And if you go light on maintenance, it'll need even more repair more often.

The results of poor maintenance are held up for public observation on tower tops across the country. Some stay aloft as tributes to the difficulty of keeping wind-electric systems going. With others, neglect and abuse becomes catastrophic, as turbines and towers fail and give their owners gray hair.

Slip rings can be misaligned and not conduct the turbine output to the down-tower wiring.

Courtesy of Ian Woofenden

Slip ring or brush failure and shorting can make sparks and fire, putting your wind generator out of commission.

Grease from a bearing failure caused this slip ring assembly failure.

Courtesy of Roy Butler (2)

Furling bushings wear out after years of operation, and need to be replaced.

Courtesy Roy Butler

The advice of two long-time wind-energy users? Take maintenance very seriously, and do it on a regular basis. Heed the message your wind-electric system is trying to send you—"Take care of me and I'll try to take care of you."

Access

Roy Butler (roy.butler@homepower.com) lives off-grid on a windy hilltop in the Finger Lakes region of New York state. Because he's frequently away, installing wind turbines and teaching installation workshops, his own turbine suffers from "mechanic's car syndrome."

Ian Woofenden (ian.woofenden@homepower.com) lives a "do as I say, not as I do" existence as a wind-electric system owner, author, tower jockey, and consultant in Washington's San Juan Islands—and can tell you from experience why you should maintain your wind generators.

Recommended Reading:

"Wind Generator Tower Basics" by Ian Woofenden in *HP105*

"A Beginner's Guide to Tower Climbing Safety" by Ian Woofenden in *HP128*

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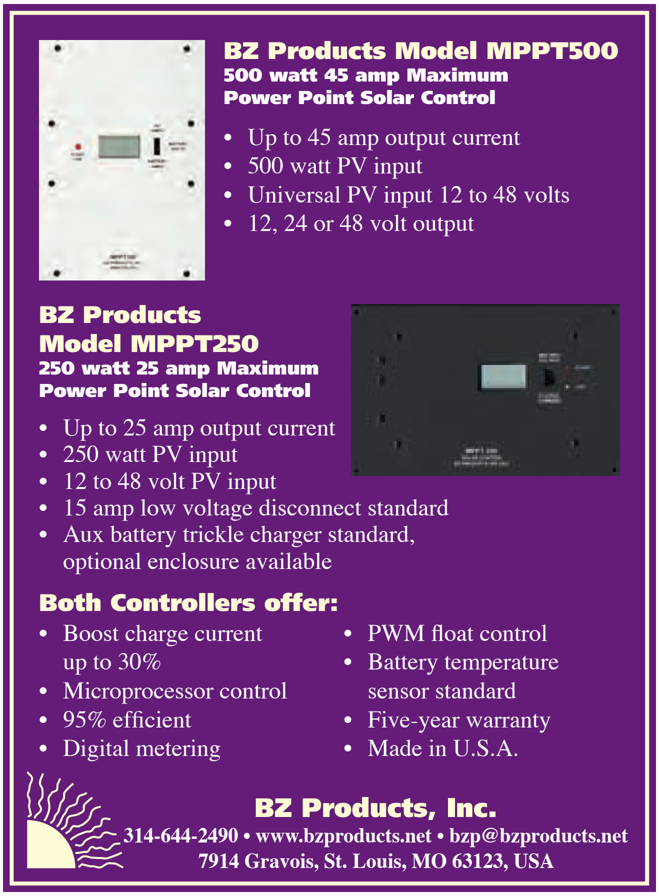

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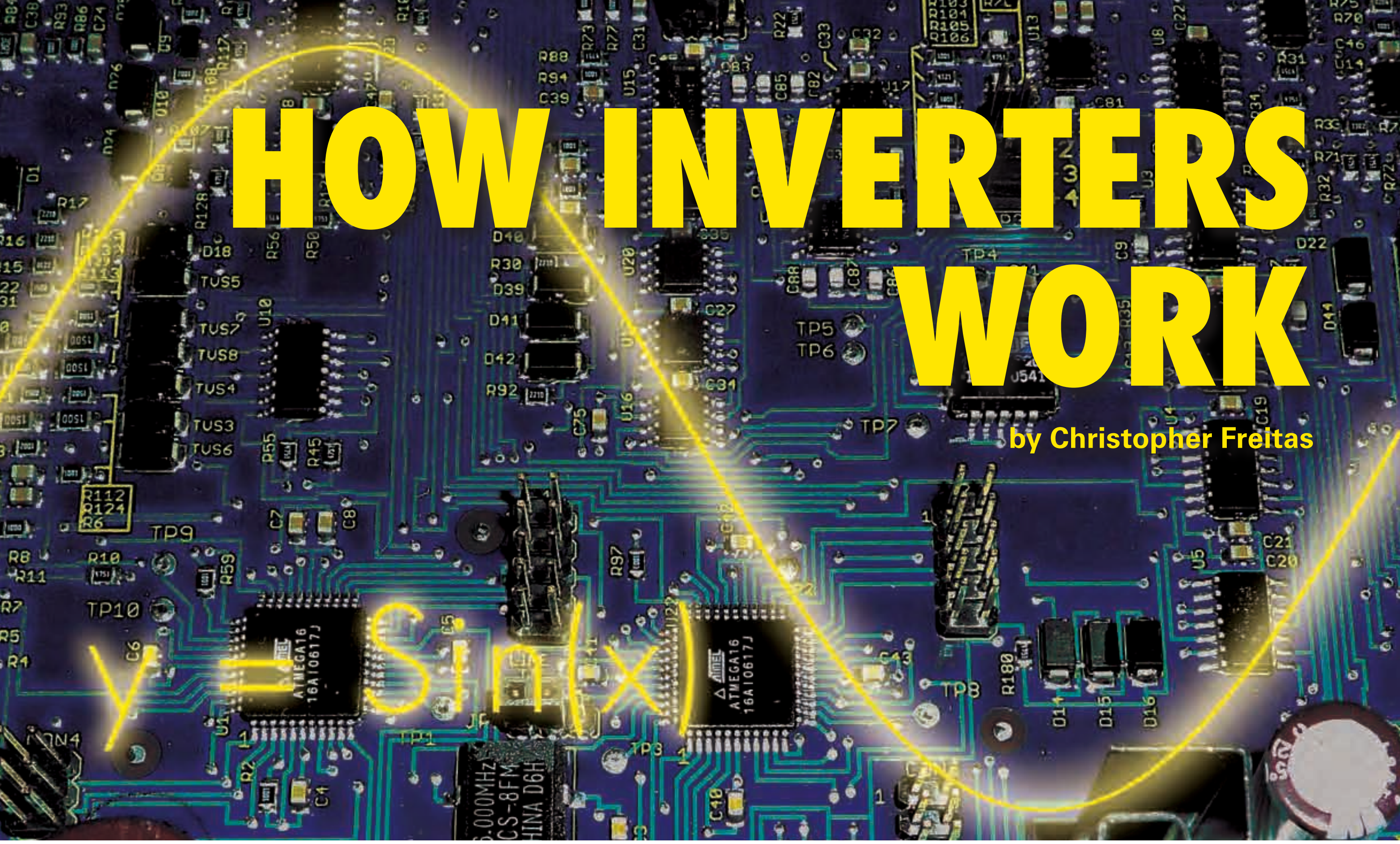
HOW INVERTERS WORK

by Christopher Freitas



The arrangement of the working parts inside of an inverter is called its "topology"—the configuration of the various electronic components that allow it to produce an AC waveform from a DC source.

Some topologies can be used to make different types of AC output wave forms (square wave, modified square wave, or sine wave), or even work in an off-grid application with a battery, or a batteryless grid-tied RE application. The difference is in the details—the quantity, type, and arrangement of transistors, capacitors, transformers, and inductors; and the sophistication of the control system utilized.

Some topologies may be suitable only for certain applications due to safety requirements and performance limitations. Although this sounds like a serious limitation, it is more of an indicator of very specialized solutions for specific applications. Transformerless inverters, which are just starting to become available in the North American marketplace just for grid-tied PV applications are an example of this.

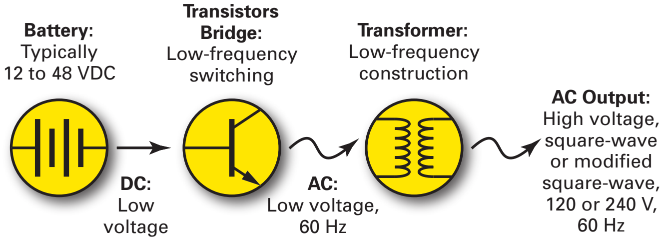
Each topology has its advantages and disadvantages. By understanding the trade-offs involved and by optimizing the components and design, the best topology for an application can be determined.

Square-Wave & Modified Square-Wave Inverter Topologies

The earliest inverters used in renewable energy applications produced a coarse square wave AC output—fairly easy to accomplish, and therefore much cheaper. Plus, they offered low losses. Early square-wave inverters were later replaced with an improved "modified" square-wave inverter design, which improved performance and appliance compatibility while using the same basic inverter topologies. Because of the low power quality, these inverters cannot be connected to a utility grid. While most current PV systems do not use these types of inverters, knowing how they work is important to understanding the evolution of inverter manufacturing.

Two different groups of square-wave inverter topologies are used to make essentially the same resulting modified square-wave AC output. There also are many additional variations within each of these two groups, but it is easiest to divide the topologies into either a low- or a high-frequency type.

Low-Frequency Modified Square-Wave Inverter



Low-Frequency Modified Square-Wave Inverters. A set of transistors first converts the DC source into a low-voltage AC wave form. The transistors are switched on and off about 120 times per second during each AC cycle—also referred to as switching at 120 Hertz. A low-frequency transformer steps up the low AC voltage to the required 120 VAC. This topology is one of the simplest inverter designs, but is limited to producing square-wave and modified square-wave AC output waveforms (see "Inverter Basics" in *HP134* for more information on AC wave forms).

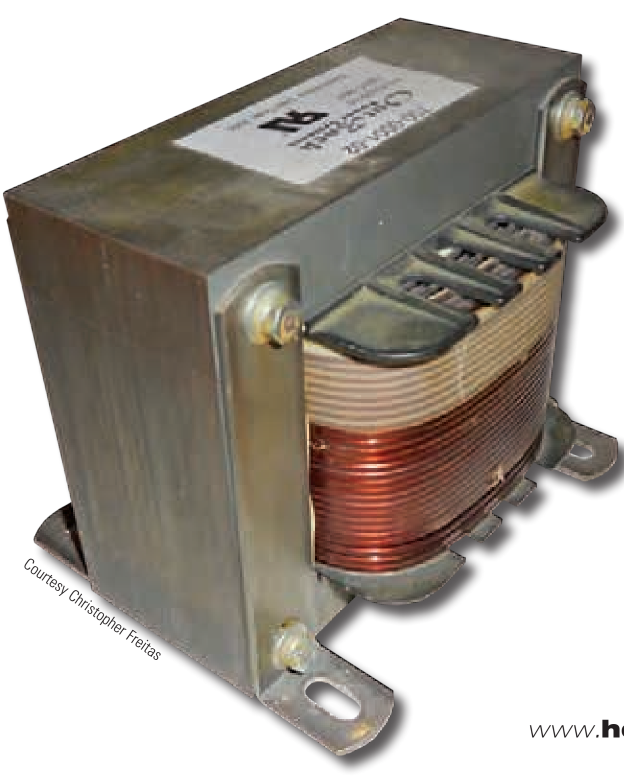
These types of inverters are easily identified by their large size and weight. The relatively large low-frequency transformer makes them heavy, but it also makes the units rugged and reliable, since the transformer also provides DC-to-AC isolation and protects the transistors from damage, sort of like a heavy bumper on a truck.

Because of the simplicity of this topology and its low parts count, fairly high efficiencies—even at low power levels—can be attained since the low-frequency switching reduces losses in the transistors and the transformer. Since all of the switching is done at low frequencies, no elaborate DC or AC filtering is required to minimize interference with loads, although AM radio interference is often encountered.

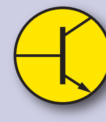
This topology is only used in less-expensive, battery-based inverters in occasional-use applications such as RVs and cabin systems, as some common AC loads do not tolerate the non-sinusoidal modified square-wave form.

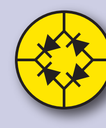
Common Brand Names: Dimensions Unlimited; Heart Interface; Magnum Energy ME series; Trace Engineering DR, RV, UX and U series; Tripplite

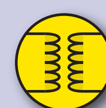
Low-frequency transformers used in inverters are often large and heavy.


Courtesy Christopher Freitas

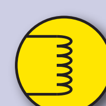
THE GUTS


Transistor—A solid-state semiconductor device used to switch the DC current source into pulses of electricity and/or into an AC wave form. The transistors are grouped together in various configurations called a "bridge," which flips or "inverts" the polarity of the DC power source—creating an alternating waveform.


Rectifier—A solid-state semiconductor device that can convert AC power into DC power. Rectifiers are typically made up of a group of diodes or sometimes transistors. Not all inverter topologies use rectification as it adds losses and requires additional heat sinks and airflow.


Transformer—An electromagnetic device, typically made of two separate copper windings on an iron or steel core, that can step an AC voltage up or down. Low-frequency transformers tend to be large and very heavy, while high-frequency transformers can be small and light.


Capacitor—An electrochemical device that can temporarily store or provide very quick pulses of electricity in an AC or DC electrical system, capacitors are often used to smooth out variations in power.


Inductor—An electromagnetic device that is used to store or provide very quick pulses of electricity in an AC or DC electrical system, often used to smooth out variations in a power source. Made of a single winding of copper on an iron core (similar to a transformer), inductors also tend to be large and heavy for low-frequency applications and small and light for high-frequency applications.


Control Board—The "brain" of the inverter that provides the electrical signals for the various components and measures and adjusts the resulting wave form and voltages. Control boards can vary from simple single-chip electrical circuits to elaborate multi-microprocessor or even digital signal processing computers.

High-Frequency Modified Square-Wave Inverter. In a high-frequency inverter, the transistors are turned on and off about 20,000 times or more per second during each AC cycle, also referred to as switching at 20 kilohertz (kHz). This topology is more complex and can be used to produce a variety of AC output wave forms, including a true sine wave.

Inverter controllers can be complex computers, but in some cases they might be as simple as a single-chip logic circuit.

Courtesy Christopher Freitas (3)

AC filters help smooth out the waveforms and reduce radio frequency interference.

With this topology, the DC source is first stepped up to a higher-voltage AC wave form by a set of transistors switching at 20 kHz and a high-frequency transformer. Then, it's rectified to an intermediate DC voltage (usually between 200 and 400 VDC), which is stored in a set of capacitors. An additional set of output transistors switching at low frequency (120 Hz) is then used to produce the modified square wave AC output from this high-voltage DC source.

These types of inverters are easily identified by their smaller size and lighter weight (compared to low-frequency units), since the large low-frequency transformer has been replaced with a much smaller high-frequency transformer. Because the output set of transistors is not isolated by a transformer, they also tend to be more sensitive to abuse and voltage surges and lightning, resulting in lower reliability.

Achieving high efficiencies (greater than 90%) with this topology can be challenging when working with low DC voltage systems, such as with battery applications. It also can be difficult to provide high "surge" currents for a long enough time period to start larger motors.

Brand Names: Powerstar UPG series, Samlex SI & SPE series, Statpower Prowat & PortaWatts series, Xantrex Xpower series

Sine-Wave Inverter Topologies

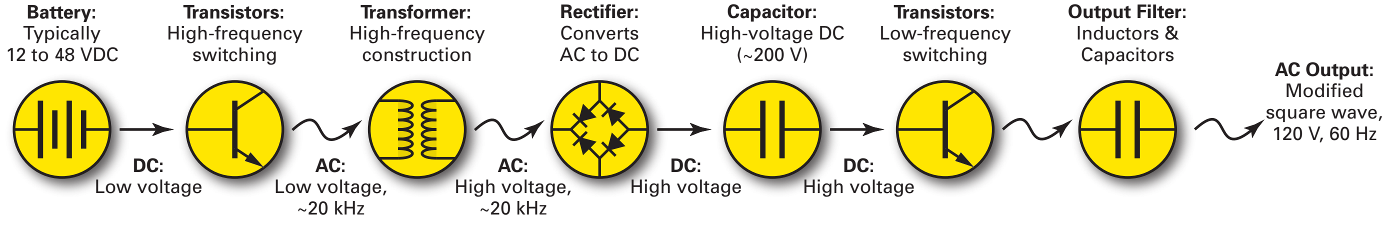
Making a sine wave from a DC source is much more difficult than making a square wave or modified square wave form. It takes more parts, more design, and a much more sophisticated control system.

The biggest challenge with making a sine wave inverter is doing it in a way that provides high efficiency. The earliest sine wave inverters were not very efficient—particularly with low-power loads. Advances in transistors and high-speed digital control systems now allow modern sine wave inverters to provide high-quality power at higher conversion efficiencies—even at low power levels.

Sine-wave inverter topologies vary from simple to complex. Each has its benefits and drawbacks—there is no "best" topology. The range of applications for sine-wave inverters is too varied.

While many of the sine wave inverter topologies can be used for both off-grid and grid-tied applications, the construction and features utilized in a battery-based inverter are very different than for one designed to be used only with a PV array as a source.

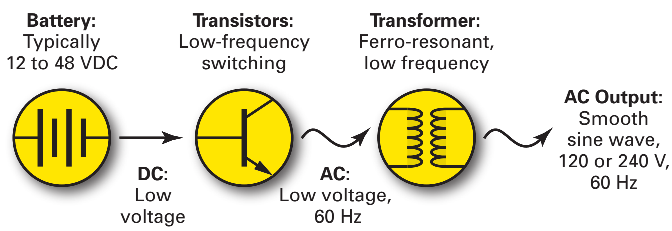
High-Frequency Modified Square-Wave Inverter



Low-Frequency Ferro-Resonant Sine-Wave Inverter. The need for a higher-quality AC wave form prompted inverter engineers to figure out how to make a better sine-wave output from the rugged and simple low-frequency square wave inverter topology. The modified square-wave form was just not good enough to operate the more demanding electrical loads and also could not be used for grid-tied applications.

The first solution used was to add a filtering system to the output, to "round-off" the square edges of the modified square wave form. Several manufacturers offered ferro-resonant transformer-based output filters, which improved the compatibility with sensitive electronic loads such as laser printers, but had a big impact on the inverter's efficiency, especially when operating at low power levels, making them unpopular for RE applications. But they have been used in high-end power supply and telecommunication markets to power sensitive loads when efficiency is not critical.

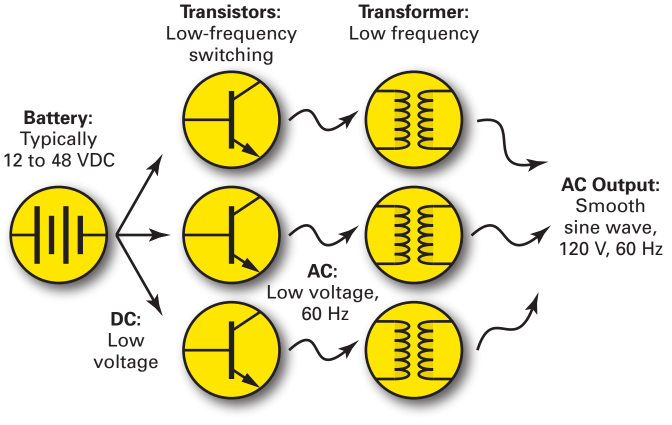
Low-Frequency Ferro-Resonant Sine-Wave Inverter

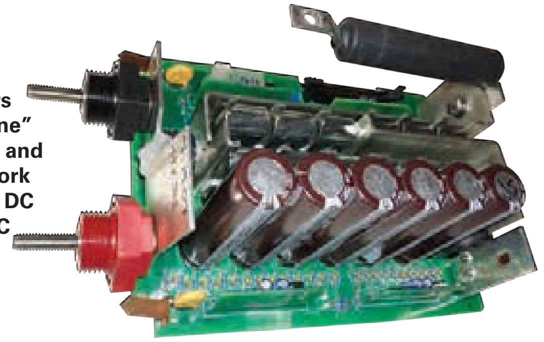


With these topologies, the quality of the sine wave form is very dependent on the characteristics of the AC load being powered, since there isn't any feedback control of the ferro-resonant transformer, so the success of this solution was hit-and-miss. This topology does not readily allow the inverter to correct or adjust the shape of the output wave form, since the transformer operates passively and is not actively controlled.

Brand Names: Alpha Technologies, Eaton Sola, MGE Topaz, Shape Magnetronics Line Tamer

Low-Frequency Multistep Sine-Wave Inverter





The bridge assembly of transistors and capacitors are the "engine" of an inverter and do the real work of converting DC power into AC power.

Low-Frequency Multistep Sine-Wave Inverter. Another solution that was developed to make the AC output closer to a true sine wave involves combining several low-frequency, inverters operating at different frequencies together in series. This allows multiple AC output voltage levels to be produced, creating a stepped sine-wave approximation of a sine wave form. This approach resulted in a surprisingly good sine wave, while still using low-frequency switching and transformers to maintain efficiency at low power levels while only modestly increasing the cost and complexity.

The AC output sine wave allows some inverters using this topology to be tied to the grid, although few manufacturers are currently using this topology due to the high parts count and resulting high manufacturing cost.

Brand Names: Trace Engineering SW & PS series; Sustainable Energy Technologies Sunergy series

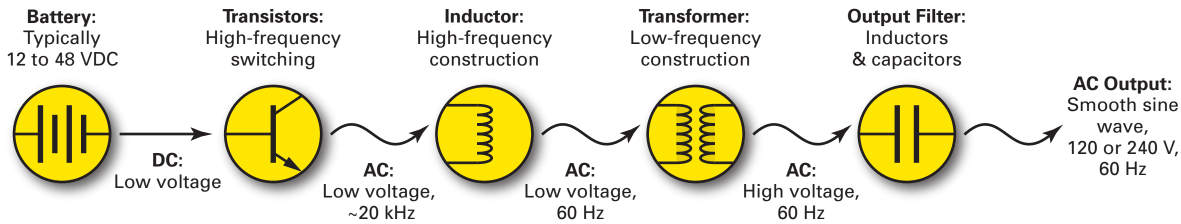
Mixed Frequency Sine-Wave Inverters. This topology combines the benefits of both low-frequency and high-frequency inverters. High-frequency switching transistors convert the DC source to a lower-voltage AC waveform. The transistors are switched at high frequency—hundreds of times per AC cycle or about 20,000 times a second. An inductor then smooths the choppy, high-frequency square wave form into a smooth, low-frequency wave form—creating a low-voltage sine wave. Then, a low-frequency transformer steps up the AC voltage to the required 120 or 240 VAC. This type of inverter is able to produce a "true" sine wave like a high-frequency inverter, but it is simpler to build and more reliable.

Because the DC currents are being switched at high frequency, which causes electrical noise, a carefully designed output filter must be included to eliminate electrical interference with loads or clean up the power being sent into the utility grid.

Like the low-frequency modified square-wave inverters, these types of inverters are also large and heavy. When used in a batteryless grid-tied PV application with high DC input voltages, efficiencies as high as 96% can be attained since the DC currents being switched are much smaller than with low-voltage battery systems.

Brand Names: Apollo Solar TSW series; OutBack FX series; Xantrex GT and XW series; SMA Sunny Boy and Sunny Island series; PV Powered PVP series

Mixed-Frequency Sine-Wave Inverter (Battery-Based)



High-Frequency Sine-Wave Inverters. Another way of producing a high-quality sine wave uses high-frequency power conversion. While significantly complex, it does allow a dramatic reduction in the size and weight compared to low-frequency sine wave inverters.

The challenge with this design is similar to the high-frequency modified sine-wave inverter—the complexity and high parts count can make reliability an issue, and efficiency at lower power levels can be unacceptable.

This topology is also used by many batteryless grid-tied PV inverters to send surplus power to the utility. In the two-step power conversion process, the control system dedicates the "front end" converter (which goes from DC to AC to DC and is comprised of transistors, and a transformer and rectifier) to extract the most power from the PV array (called maximum power point tracking), while the second converter comprised of transistors and an output filter (capacitors and inductors) is optimized to put the most power back into the utility grid.

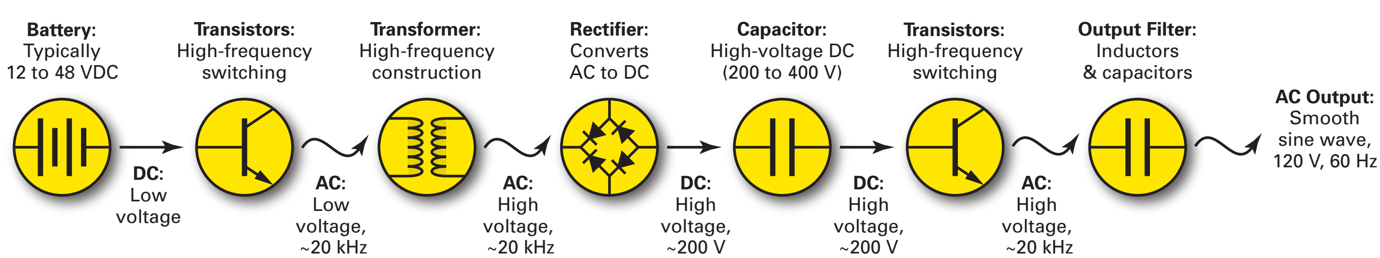
Brand Names: Exeltech XP series; Fronius; Xantrex ProSine; Solectria PVI series; SMA SB HF series

High-Frequency Transformerless Sine-Wave Inverters. This topology is starting to become available as inverter manufacturers compete to offer the highest efficiency inverter at the lowest cost for grid-tied PV applications. Removing the transformer eliminates its losses, allowing inverter efficiencies up to 98%.

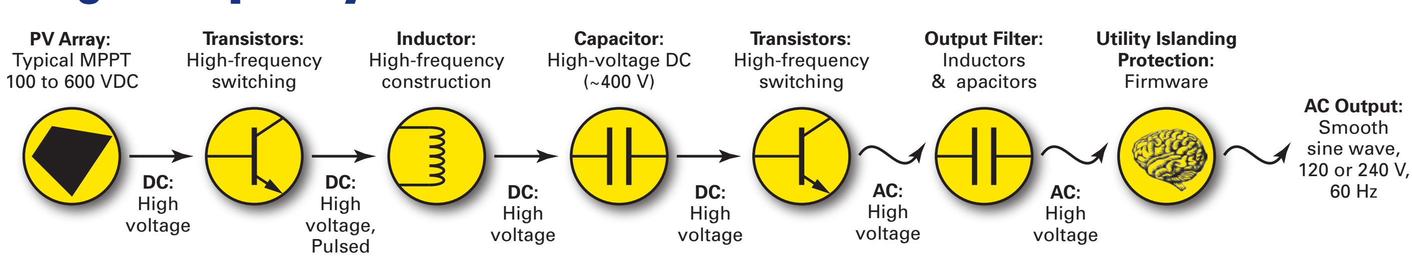
However, removing the transformer from the inverter introduces a new problem: the PV array's DC output cannot be grounded. The PV array is connected to the utility grid at low frequency (60 times a second) in a "positive" and "negative" configuration—which requires that the PV array be "floated," with neither the positive nor negative DC conductors grounded. In essence, the inverter's transistor bridge "flips" the PV array with respect to ground 60 times a second. This scenario was not permitted under *National Electrical Code* guidelines until recently. In Europe, ungrounded electrical systems are commonplace, making the switch to transformerless inverters much easier.

Transformerless inverters are not likely to be used in battery-connected applications (e.g., off-grid systems), since the battery cannot be grounded with these types of inverters,

High-Frequency Sine-Wave Inverter (Battery-Based)



High-Frequency Transformerless Sine-Wave Inverter



Inverter Topology Attributes

Modified Square Wave	Sine Wave Output	Efficiency	Idle Power Draw	Reliability	Weight
Low frequency	No	High	Low	High	Heavy
High frequency	No	Moderate	High	Low	Light
Sine Wave					
Low-frequency, ferro-resonant	Yes*	Moderate	High	High	Heavy
Low-frequency, multistep	Yes	High	Low	Moderate	Heavy
Mixed frequency	Yes	High	Low	High	Moderate
High frequency	Yes	Moderate	High	Moderate	Light
High-frequency, transformerless	Yes	High	Low	High	Light

*Load dependent

which would increase hazards present on the serviceable connections of the battery. Also, the changes made to the *NEC*, which allow ungrounded systems, were limited specifically to on-grid PV array applications. Transformerless inverters can be utilized in an AC-coupled application with a transformer-equipped stand-alone inverter as this allows the battery to be grounded and the PV array to be ungrounded.

Brand Names: Power-One PVI series

Access

Christopher Freitas (cfreitas@sunepi.org) has worked in the PV industry since 1986 as an electrical engineer. He has participated in the development of many UL, *NEC*, and IEEE standards and volunteers for developing-world RE projects with Sun Energy Power International (www.sunepi.org). He lives in an off-grid solar and microhydro-powered home in Washington state.

Inverter

Supply-Side Connections

by John Wiles

Supply-side (of the service disconnect) connections must be used for many larger PV systems, which cannot meet the requirements for a load-side connection to the premises wiring system.

Code Considerations

A supply-side connection (a.k.a. service-entrance connection) is allowed by the *National Electrical Code (NEC)* and is addressed in a number of sections in the *Code.*

Section 690.64(A)—moving to 705.12(A) in the 2008-2011 *NEC*—allows a supply (utility) side connection as permitted in 230.82(6).

Section 240.21(D) indicates where service-entrance conductors shall be protected and refers to 230.91. In general, the other "tap rules" of Section 240 do not apply—they were not developed to address two sources of power in a tap circuit, nor were they developed to assure safe operation when one source is an unprotected utility power source.

Section 230.91 requires that the service overcurrent device be co-located with the service disconnect. A circuit breaker or a fused disconnect would meet these requirements. A utility-accessible, visible-break, lockable fused disconnect (a.k.a. safety switch) used as the new PV service disconnect may also meet utility requirements for an external PV AC disconnect if utilities require such an additional disconnect.

Section 230.71 specifies that the service disconnecting means for each set of service-entrance conductors shall be a combination of no more than six switches and sets of circuit breakers mounted in a single enclosure or in a group of enclosures. The PV system may be counted as a separate service (230.2) and could have up to six disconnects of its own.

Section 230.70(A) establishes the location requirements for the service disconnect. This requires the service disconnect to be installed at a readily accessible location, either outside the building or inside the building, nearest the point of entrance of the service conductors.

Section 705.10 requires that a permanent sign or directory, showing the location of all power sources for the building, be placed at each service-equipment location. Locating the PV AC disconnect adjacent to or near the existing service disconnect may facilitate the installation, inspection, and operation of the system, since one simple Power Source plaque can be used at a central location, rather than having to create a directory and map out where all the other service-entrance equipment is located.

Sizing

The new PV service disconnect will normally be sized at 125% of the rated output current of the inverter(s). But for small systems, how small can the service disconnect be? Section 230.79 addresses the rating issue. Some inspectors interpret 230.79(A) to allow a disconnect rated at 15 amps—if that value is at or above the inverter output circuit's rating.

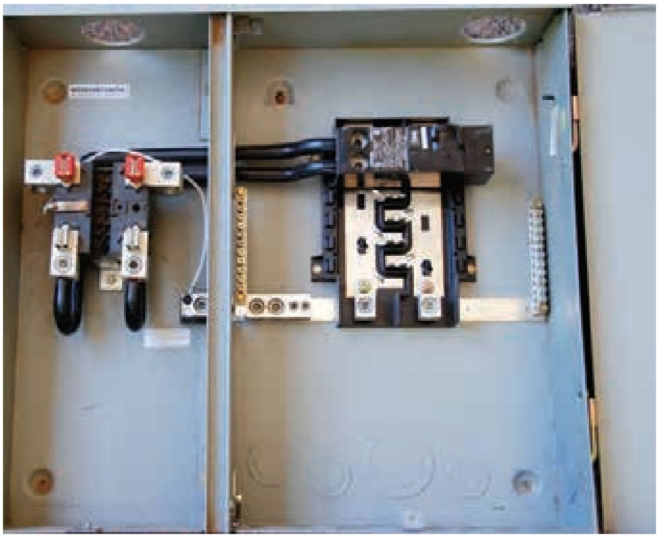
However, caution is advised, since the PV system is connected to service-entrance conductors rated at 100 A and above. In this application, a typical 15 A circuit breaker with 10,000 A of interrupt capability may not be able to withstand the potential fault current since it is not protected and coordinated with any main breaker typically rated at 22,000 A. Of course, section 110.9 should be followed and fault current calculated (see below). A service-entrance-rated 30 A fused disconnect can be used, since the proper fuses will have sufficiently high interrupt ratings.

Another consideration is the size of the service-entrance conductors, the new PV connection conductors, and the terminals on available switchgear likely rated at 30 or 60 A. The added conductors between the existing service-entrance conductors and the new service disconnect may be subjected to available fault currents and will have no protection except that provided by the fuse on the utility transformer's primary side input. Sizing these conductors as large as possible with an upper limit of the existing service-entrance conductor size would seem prudent, but small disconnects will not accept very large conductors.

Therefore, I suggest that Section 230.79(D) be used as the requirement for the smallest service disconnecting means for PV inverter supply-side taps. This section requires that the disconnect have a *minimum* rating of 60 A. This would apply to a service-entrance-rated circuit breaker or fused disconnect.

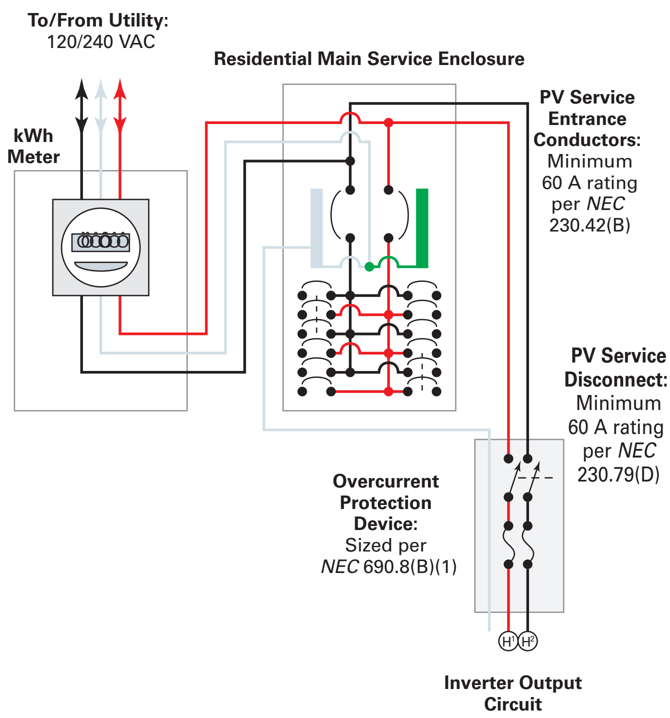
The service connection conductors (the conductors coming from the PV service disconnect that connect to the existing service entrance conductors) must have a minimum rating not less than the service disconnecting means per 230.42(B), which we have determined to be 60 A, as specified in 230.79(D). The rating for the conductors between the inverter and the PV service disconnect should be based on 125% of the rated output current for the utility-interactive PV inverter, as required by 690.8. Temperature and conduit-fill factors must be applied for sizing.

For a PV system with a 2,500 W, 240 V inverter that calls for a 15 A circuit and overcurrent protection, *Code* requirements



Even with all this room, putting a supply-side tap in this combined meter and service disconnect box would not fall within its listed use, and should not be done.

Typical Residential Supply-Side Connection



call for a minimum 60 A disconnect, with 15 A fuses; fuse adapters that allow the smaller-bodied 15-amp fuse to be installed in the larger 60-amp fuse holder would be needed. Conductors sized to handle 15 A could be used between the inverter and the 15 A fuses in the disconnect, provided these conductors are large enough to keep the voltage drop within the limits of the inverter AC output circuit. Section 230.42(B) requires that the conductors between the service connection and the disconnect be sized to handle not less than the rating of the disconnect—in this case, 60 A.

Section 110.9 requires that the interrupt capability of the new disconnect/overcurrent device be sufficient to handle the available fault current. In most cases, this means these interrupt ratings have to be at least equal to the interrupt rating of the existing service equipment. The utility service should be investigated to ensure that the available fault currents have not been increased above the rating of the existing equipment. Fused disconnects with RK-5 fuses are commonly available with interrupt ratings up to 200,000 A, which will exceed the interrupt requirements for nearly any PV installation.

Section 230.43 allows a number of different service-entrance wiring systems. Considering that the PV service connection conductors are unprotected from faults, it is suggested that the conductors be as short as possible, with the new PV service/disconnect mounted adjacent to the connection point. Making these PV conductors as large as the service-entrance conductors, while not a *Code* requirement, would also add a degree of safety. Of course, the added disconnect must accept the larger conductors. Conductors installed in rigid metal conduit would provide the highest level of fault protection.

All equipment must be properly grounded per Article 250 requirements. See 250.24(B) for bonding requirements. As a service disconnect, neutral-to-ground bonding would generally be required at the new disconnect, even though the nearby existing service entrance has a similar neutral-to-ground bond. Any stray currents in the equipment grounding conductors are expected and accepted.

The actual location of the new service connection will depend on the configuration and location of the existing service-entrance equipment:

- On some residential and commercial systems there is sometimes room in the *main load center* to splice to the service conductors just before they are connected to the existing service disconnect.

  In other installations, the *meter socket* has lugs that are listed for two conductors per lug. Of course, adding a new *junction box* (where the splice can be made) between the meter socket and the service disconnect is an option. Combined meter/service disconnects/load centers frequently have enough apparent interior space to make a connection between the meter socket and the service disconnect. However, tapping this internal conductor or bus bar in a listed device such as a meter/main combination would violate the listing and should not be done.

  In situations where the service-entrance conductors are accessible, a new *meter base* (socket) could be added ahead of the combination device. A *splice box* would then be added between the new socket and the combination device. The meter would then be moved from the combination device to the new socket, jumper bars added to the old socket, and the old socket covered.

Besides not being code-compliant, tapping into the bus bar on this combination meter/service disconnect can violate the equipment's UL listing.

- In larger installations, the main service-entrance equipment will frequently have bus bars with holes that can be used for making additional connections. The addition of any terminals to the bus bar—and sometimes the actual connection—can only be made by the organization supplying the service equipment, usually a UL508 panel shop. They can modify the equipment and still maintain the listing on the equipment. These organizations must control, by specification, labeling, instructions, or direct participation, any new connections made to the equipment.

In all cases, the utility service must be de-energized before any connections are made. Additional service-entrance disconnect requirements in Article 230 and other articles of the *NEC* will apply to this connection.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. John provides engineering support to the PV industry and a focal point for PV system code issues.

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV" and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices* by John Wiles

Hacking Climate Change

by Michael Welch

Once again, the entire concept of a dangerous, human-caused change in climate is under attack. Those opposing dealing with the problem are using anything they can to bolster their position—the latest being a bunch of e-mails stolen from a server by hackers. These e-mail exchanges, claim the climate-change naysayers, show that scientists have manipulated data to support their theory of human-caused climate change.

Without this data, climate-change skeptics—and verifiers alike—are not able to take a second look at how the University of East Anglia's Climatic Research Unit (CRU) reconstructed past climate and temperatures, which ultimately showed a 0.8°C temperature increase over the past 157 years, according to *The Times* of London. *The Times* also reported that the data had been lost in the 1980s and was "one of the main pieces of evidence used by the Intergovernmental Panel on Climate Change (IPCC), which says global warming is a threat to humanity." The IPCC was established by the United Nations, and is the leading scientific body that assesses climate change.

This has caused quite a stir among climate-change watchers—notice of the loss came just days before the United Nations climate-change talks in Copenhagen last December. But despite the latest brouhaha, no scientists, skeptics, or activists are changing their minds about anything. However, the announcement could have an effect on individuals who were on the fence, otherwise prone to conspiracy theories, or just uninformed. And the adverse news may have the unfortunate result of forestalling some efforts at reversing the warming trend, as governments and organizations hold hearings and crank out reports addressing this distraction, rather than tackling climate change itself.

In a joint release by several prominent climate scientists, Professor Michael Mann, director of Earth System Science Center, said:

> *Decades of research [has been conducted]. There is a very robust consensus that humans are warming the planet and changing the Earth's climate.*
>
> *There are a handful of people and organizations who have tried to cloud the debate…they have engaged in this eleventh-hour smear campaign, where they have stolen personal e-mails from scientists, and mined them for single words or phrases that can be taken out of context to twist their words, and I think this is rather telling…Those advocating inaction don't have the science on their side, so they turn to this last-minute smear campaign.*

According to the IPCC, the key finding in their most recent assessment report was that "the warming in the climate system is unequivocal." In a press release also addressing the stolen e-mails, IPCC said the finding "is based on measurements made by many independent institutions worldwide that demonstrate significant changes on land, in the atmosphere, the ocean, and in the ice-covered areas of the Earth." The release further stated, "The body of evidence is the result of the careful and painstaking work of hundreds of scientists worldwide. The internal consistency from multiple lines of evidence strongly supports the work of the scientific community, including those individuals singled out in these e-mail exchanges."

In the meantime, the World Meteorological Organization announced just before the Copenhagen talks that 2009 was, with data so far, the fifth warmest year since the beginning of instrumental climate records (1850) and that this decade, so far, has been warmer than the 1990s—the warmest decade that has been recorded.

Beyond Smear

But smear-and-fear campaigns are not the only things harming efforts to reverse human-caused climate change. Both the fossil-fuel industry (with coal's oxymoronic burn buzzword "clean coal") and the nuclear industry continue to push their dirty products on the world—which only serves to divert attention and funds away from the real problem at hand.

It is difficult to paint a smiley face on mountaintop removal, offshore oil derricks, or belching smokestacks, and PR campaigns have not swayed the public that coal is good. But the nuclear industry, with its invisible effluents and mostly out-of-view plant sites, is seeing some success promoting the idea that nuclear energy might be a solution to human-caused climate change.

One problem with news and knowledge regarding the nuke industry is that, for the most part, there are just two sources of information on its success and its failures. The biggest source is the industry itself, which encompasses the nuclear corporations and their PR firms, the world of nuclear-related academics, and the regulatory bodies—

which are mainly made up of industry insiders. The second set of sources for nuclear energy information comes from nonprofits and groups that oppose the use of nuclear energy.

Each source makes claims about the other. So who's right? It is a matter of who you choose to believe. But there is a third, small category of information sources, made up of nongovernmental, independent research groups. Often trained from within the same system that trains nuclear physicists and technicians, these groups have the reputation—along with the necessary knowledge—to be considered independent sources of information.

One such organization that's well respected for its accuracy in reporting and for the use of government documentation and scientific literature for its research is the Institute for Energy and Environmental Research (IEER), headed by Arjun Makhijani, who has a Ph.D. in nuclear engineering.

Renewable Solutions

Makhijani has entered the climate fray with an important book, *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (available by download from www.ieer.org). In this book, he states and expands the premise that a widespread use of nuclear energy to meet the challenge of climate change could lead to nuclear weapons proliferation. He adds and also expands the premises that something must be done to avoid severe climate change, and that there is a security problem with most of the oil reserves being in the Persian Gulf.

The book goes into significant details about its conclusions and findings. Among the many findings are these:

- A reliable U.S. electricity sector with zero-CO_2 emissions can be achieved without the use of nuclear power or fossil fuels. How? Intermittent solar and wind resources can be augmented by hydro power, with biofuels and geothermal as baseload electricity sources.

- The use of highly efficient energy technologies and building design…can greatly ease the transition to a zero-CO_2 economy and reduce its cost. A 2% annual increase in efficiency per unit of GDP [gross domestic product] relative to recent trends would result in a 1% decline in energy use per year, while providing 3% GDP annual growth.

- Biofuels, broadly defined, could be crucial to the transition to a zero-CO_2 economy without serious environmental side effects or, alternatively, they could produce considerable collateral damage or even be very harmful to the environment and increase greenhouse gas emissions. The outcome will depend essentially on policy choices, incentives, and research and development, both public and private.

- Much of the reduction in CO_2 emissions can be achieved without incurring any cost penalties (as, for instance, with efficient lighting and refrigerators). The cost of eliminating the rest of CO_2 emissions due to fossil fuel use is likely to be in the range of $10 to $30 per metric ton of CO_2.

- The transition to a zero-CO_2 system can be made in a manner compatible with local economic development in areas that now produce fossil fuels.

Makhijani outlines what he calls "the clean dozen"—the 12 most critical policies that must be enacted "as urgently as possible" to attain a zero-CO_2 economy—without the use of nuclear energy.

Access

Michael Welch (michael.welch@homepower.com) is still picking interesting tidbits out of Makhijani's book.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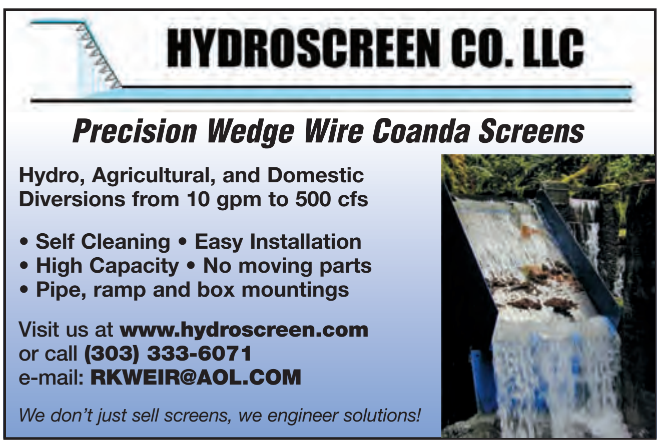
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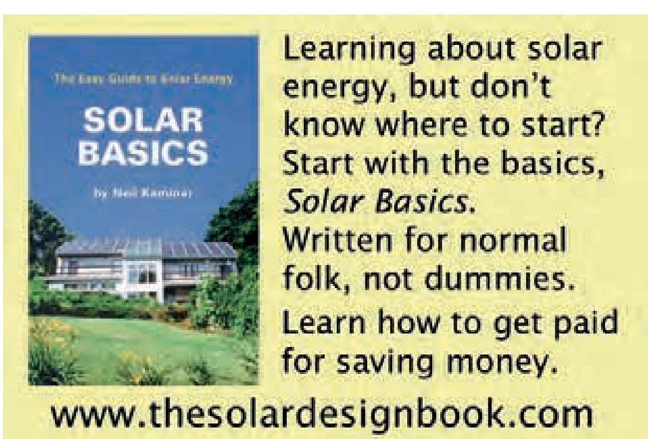
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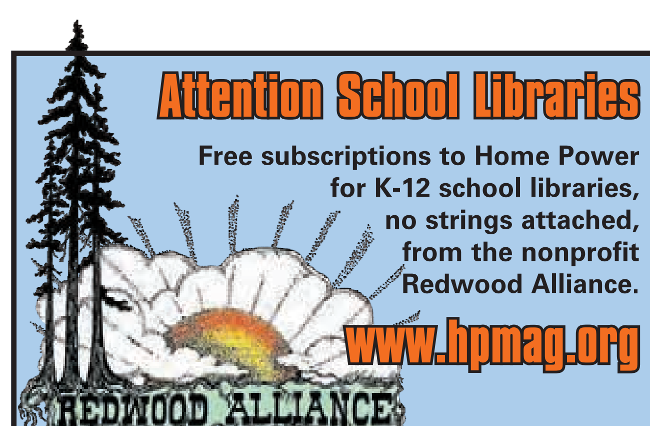
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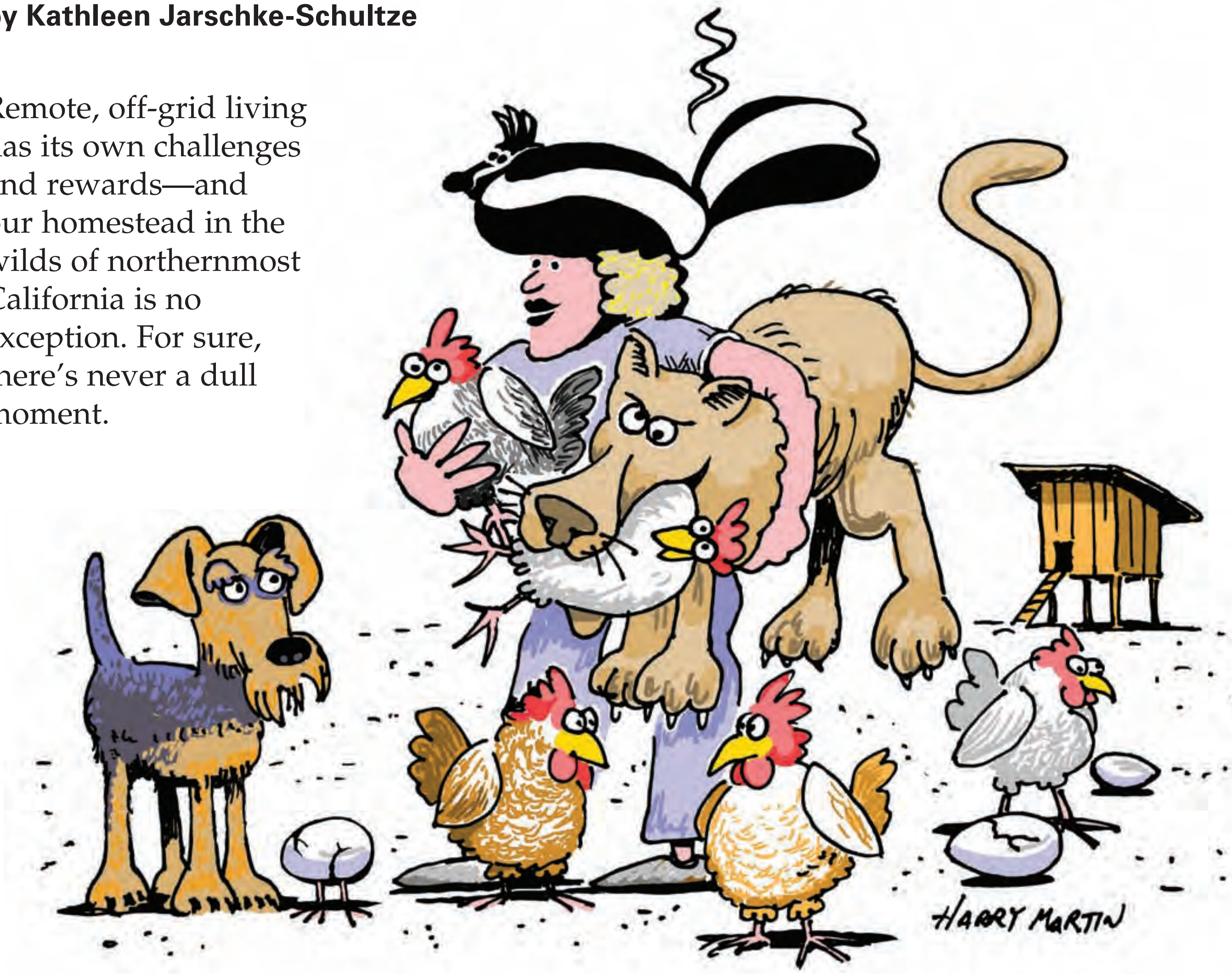
Three Tails—

er, Tales—of Off-Grid Life

by Kathleen Jarschke-Schultze

Remote, off-grid living has its own challenges and rewards—and our homestead in the wilds of northernmost California is no exception. For sure, there's never a dull moment.



Cat-astrophe

Recently, I returned from a 2 1/2-hour round trip to town, to take a cat to the pound. I had live-trapped the cat—formerly someone's pet—that had been dumped on our lonely road. I saw it crouching and sneaking toward my free-ranging chickens, so it had to go.

We had been seeing this calico cat for a couple of weeks. My husband Bob-O surprised it as it napped in the sun, down by the shop. I saw it drinking from the water I set out for the chickens by my greenhouse. We weren't alarmed by its presence, since we're accustomed to seeing the occasional feral cat out here. Sometimes they hang around for a while. But when they see us, they run, so there's no danger of triggering Bob-O's allergies. Plus, while a feral cat hangs around, we have fewer depredations.

So my first thought was that I had trapped one of these feral cats. But when I dropped food through the wire mesh for it, the cat purred and rubbed against the side of the cage. It was calm, and after eating, lay down and took a nap. I was certain it had been somebody's pet.

I called a friend who rescues abandoned dogs and asked about my choices of action. I didn't want to take it to the animal shelter, where I felt its survival was at risk, since shelters are chronically overpopulated with unwanted pets, especially cats. My friend called around to find out if I had any other options.

Two days passed, during which I was able to open the cage enough to put in food and water and a small tray of sand for a litter box. The cat itself was in good humor the whole time. I could not bring it into the house, so I put down several layers of bubble wrap and set the cage on top of that. At night, I covered the cage with wool blankets for insulation.

After the second day, I began to feel desperate. I couldn't keep the cat in the cage much longer. I called my friend and told him if we couldn't find a home by the next morning, I would take it to the county animal shelter. He said to stop by on the way in, and he would take a picture of the cat and post it on his Facebook page.

I loaded the cage into my pickup with a feeling of dread, since I felt like I was taking this animal to its doom. I cursed the person who dumped the cat and made me do their dirty work.

After stopping at my friend's house to take the cat's picture, I continued on to the animal shelter. The lady there saw something I hadn't—and knew the significance of it. One of the cat's ears had been slightly docked.

This meant the cat had already been through the system, had been spayed, and had been adopted. She said this made the cat's chances of a second, and, I hope, more successful adoption greater, since we knew she could not be pregnant. My friend wanted me to leave his phone number in case this cat's last day on Earth was approaching. The lady took his number, but assured me that it was a no-kill animal shelter. My relief was huge.

I think that it is crueler to dump a pet than to take it to an animal shelter, regardless of the consequences. Contrary to popular belief, house cats do not survive well in the wild. They are too tame and used to being fed. They may catch small rodents for a while, but are usually caught by a larger predator—we call this the "food for wildlife" program. This is true of dogs, also. Besides being cruel, dumping a pet is also a crime. Here in California, if you get caught, the fine is $1,000.

Lions & Chickens & Skunks, Oh My!

The week before we moved into our house (many years ago), we were staying at our cabin on the Salmon River. It was a sunny day and our dog was sleeping in the front yard. I heard the chickens squawking loudly in the orchard behind the cabin, and thought they had seen a snake in the grass or some such. But Francis the rooster, Bob-O, and I decided to investigate.

What we saw at the upper end of the orchard, where the forest met the clearing, was a mountain lion with one of our hens in its mouth. The hen was clamped so tight in its jaws that the chicken's wing was spread flat. That cougar looked right at us, twitched its arm-thick tail back and forth slowly, turned, and melted into the trees—with our chicken. My dog slept through the whole thing, for which I was grateful.

I now have assorted sizes of live traps for the wild—and domesticated—animals that start to hang around to raid the compost or eye my chickens. Unfortunately, everyone loves chicken, especially varmints. But I did not have my traps or call the county trapper until I lived here. So, of course, I had nothing large enough to catch this enormous cougar kitty.

I kept the chickens in their coop until we moved to our new house. There, I quickly turned a small shed into a coop, but it did not have a run yet. For a month or so, the chickens ranged at will.

I went to collect the eggs one day and did one of the quickest U-turns you ever saw. There was a skunk sleeping in one of the nest boxes. "Now what?" I thought. But I knew that skunks are nocturnal, so I set my alarm for the wee hours before sunrise and left the door to the coop open that night. Two nights went by and the skunk did not leave. The chickens would go into the coop at night—and roost right by the skunk.

So I called the county and they directed me to the county trapper—a service funded through our county taxes. He came out the next day with a cage trap. We wrapped plastic around the sides in case the skunk sprayed. We eased a milk crate close to his nesting spot and placed the trap right up against the opening. We stood outside the coop in the gray, cold, drizzly day, and stuck sticks through the cracks to wake up and goad the skunk into the trap.

Prompted by our prodding, the skunk woke up, moved to the next nest, and began munching on an egg. We had been standing in the rain an hour or more and we were both wet and cold. Finally, I told the trapper I understood he had tried his best—and that it was okay to shoot the egg-sucking thief. He did; it sprayed. When he pulled its corpse out of the nest, it had open sores on its head and paws. This freaked me out so much I gave away my flock and began planning the Chicken House of Mystery (see *HP101*).

What I found out that day is that even if we had been able to lure the skunk into the trap, and even if it did look healthy, the trapper would still have had to kill it. It's the policy of the county here. That is why I have my live traps and don't have the trapper come anymore. I have called him since, however, for good advice on where to successfully release wild animals that I trap. Here in our rural county, it's a question of distance rather than location. Too close and the animal will come right back, now wary of the trap!

Concatenation

Any animal, domestic or wild, deserves our best efforts to do the right thing—especially when you're living in such close proximity with them. What is right depends on the animal and the circumstances. I have killing traps, which I use for gophers, moles, wood rats, mice, and ground squirrels. If we kill an animal, it is done quickly and the carcass buried. Whatever your belief on this, you must determine some course of action. Doing nothing is rarely an option. Living in the woods ain't for the faint-hearted. As John Wayne once said, "Ya gotta be tough to make it out here."

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is steeping in her new wood-heated hot tub at her off-grid home in northernmost California.

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Virginia, cont.

Virginia Renewable Energy A division of Schulz Homes Corp has been serving Northern Virginia since 1987. We specialize in building Hybrid Homes using Renewable Energy Systems, including grid-tied Solar PV. We also retrofit Solar PV to existing homes and businesses . 5 N. Hamilton St., Middleburg, VA 20017. Learn more at www.schulzhomes.com/solar. Email: info@schulzhomes.com. Call 540-687-3367

Washington

SolarWind Energy Systems, LLC P.O. Box 1234, Okanogan, WA 98840 509-422-5309 www.solar-wind.us WA Cont. # SOLARES983RQ. Serving Eastern WA & Northern ID grid-tied & off-grid RE systems. Solar PV, wind, solar hot water, remote stock watering. Design, installation, service, maint. Solar Energy International (SEI) trained. Lic. & bonded. bclark@solar-wind.us or jmartin@solar-wind.us

Wyoming

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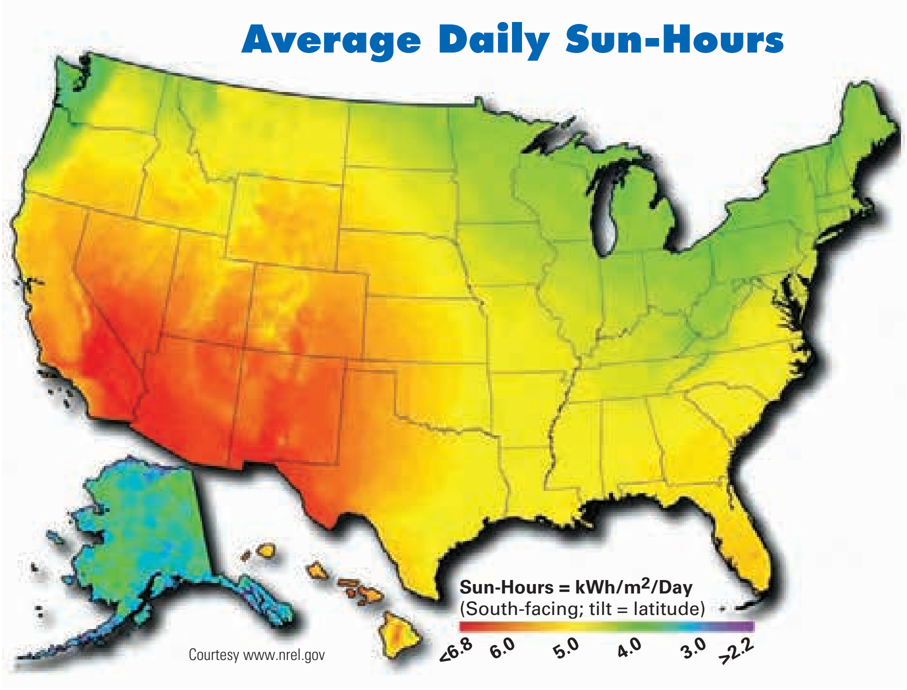
Irradiance & Insolation

The terms irradiance and insolation are commonly confused and misused. While both refer to the amount of solar resource, *solar irradiance* describes the amount of solar power available in a fixed area. Solar irradiance accounts for radiation from all wavelengths of light—from short ultraviolet to visible to long infrared. Irradiance is typically expressed in watts per square meter (W/m^2). Irradiance meters, sometime called pyranometers, display the instantaneous power available from the sun. The sun emits a consistent amount of energy, but here on Earth, we only receive a portion of this energy through the atmosphere—approximately 1,000 W/m^2 at the earth's *surface*. This value is nominally "1 sun" and is used as a reference point. A clear, sunny day may measure about 800 to 900 W/m^2. A cloudy, rainy day may be lucky to have 100 W/m^2 available. At higher altitudes on sunny days, or with additional reflection from snow or off the edges of clouds, irradiance may exceed 1,000 W/m^2.



A solar resource map shows kWh/m^2/day, or the number of full sun-hours per day available, averaged over the course of the year for various regions.

Insolation is the amount of solar irradiance that hits a surface over a period of time, and thus a measurement of solar radiation *energy*. The name comes from a combination of the words *incident*, *solar*, and *radiation*. Typically, the *energy* of the sun is expressed in kilowatt-hours per square meter per day (kWh/m^2/day) for a particular location, orientation, and tilt of a surface. Since 1,000 W/m^2 is 1 sun, 1 hour of this ideal sun produces 1,000 watt-hours of energy per square meter (Wh/m^2). For each 1,000 Wh/m^2 (1 kWh/m^2), the surface experiences 1 full sun-hour. Colorful maps of solar potential display solar energy in kWh/m^2/day, which is equivalent to the number of full sun-hours per day.

Courtesy www.eko-usa.com

A pyranometer measures irradiance.

PV modules are rated by how much power they will produce at 1 sun (1,000 W/m^2) of irradiance. The 1,000 W/m^2, together with a 25°C temperature, make up the standard test conditions (STC). The number of sun-hours at your site is an important design consideration for any solar PV system, as it is a major factor in determining how much energy a PV array can generate over the course of the day.

For example, Midwestern states average 4.5 kWh/m^2/day or 4.5 sun-hours per day of insolation, while the Southwestern states average 5.5 sun-hours each day. So, without accounting for system losses, a 1 kW array could produce 4.5 kWh per day in the Midwest, while the same array could produce 5.5 kWh per day in the Southwest. In addition, summer provides more full sun-hours than winter. Over the course of a day, due to the amount of atmosphere the sunlight has to penetrate, irradiance at the PV modules starts out low at sunrise, peaks when the sun reaches its maximum height, and then declines as the sun sets. Note that sun-hours are *not* the same as daylight hours. So, for example, while a site might experience 12 hours of daylight on a given day, only 5 peak sun-hours may be available to serve your PV system.

—Erika Weliczko