Our Photovoltaic (PV) Solar Electrical System - 2012

Power can be stored on-site using a variety of battery chemistries including the old lead-acid, deep-cycling variety, improved by better construction, lower maintenance, and longer useful life before recycling. We originally used four, 375 amp-hour, 6-volt batteries wired in series-parallel configuration to obtain 12 volts and 750 amp-hours (seen above, at the left). Our batteries before that were Thomas Edison's nickel-iron cells using potassium hydroxide electrolyte, manufactured in the 1920's. They were built for severe conditions and industrial use, and could be restored by simply changing electrolyte every 10 years. But we switched to lead-acid mainly because it's getting harder to find replacements for mechanically damaged cells or to find additional cells. There are Chinese models made now, but the quality is not up to Edison's standards! For some time we were using the set-up shown above, with lead acid wet cells and gel cells in parallel. Now we just use the lead-acid gel batteries seen above at the right. The wet cells were recycled after nearly 10 years of use. Now we have no fluids to add, no gases given off, and twice the battery life at the same rate of use.

Power that exceeds what you can economically store must be either "dumped", "blocked", or "diverted". A charge controller usually blocks excess power input. But some models allow the use of a "grid intertie", a "dump load" or a "divert load". Connecting to the grid is not our preferred choice. But the latter two are types of appliances that "burn off" excess power while doing something useful. **If you burn natural gas or propane (LP) to heat water, heat your home, or cook a meal, a charge controller can automatically switch on electrical versions of these loads for you.** This allows you to have enough generating power to keep up with electrical demand even on cloudy or windless days. And it gives you the option to power loads that would normally burn fuels.

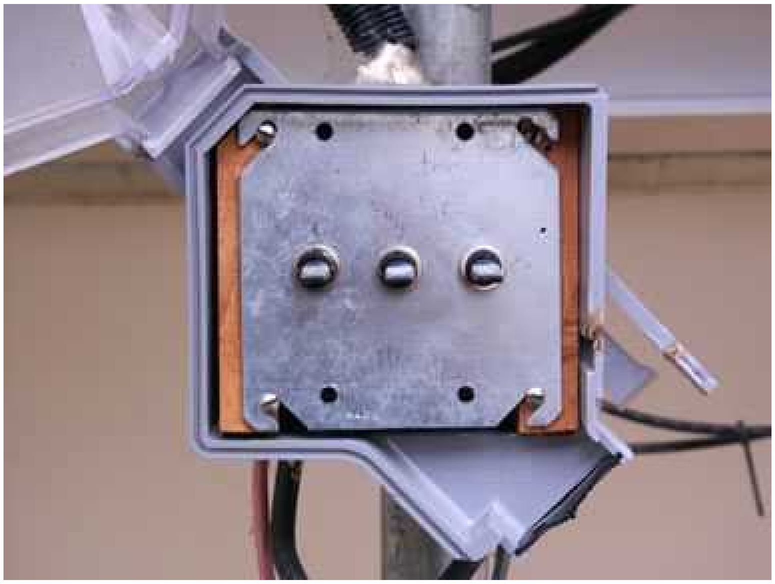
This is a 300-watt, 0.5-ohm, 12-volt air heating resistors made by Ohmite. Putting four of these in parallel gives you enough heat to make your own low-voltage oven, which is what we have done, for when we have too much energy in the winter. We often find that our [masonry stove]() gets our water quite hot enough without additional solar energy, and we need to either use the excess for something like baking or the controller will simply reduce our solar input electronically, "wasting" valuable sunshine. In 2011 we swapped 2 of these for two 30-watt resistors, allowing us to also use the oven as a yogurt or tempeh incubator.

Some of what is now used for home energy systems got its start in the military. Above is a close-up of the water-saving battery caps we used in the old lead-acid “wet cells”. Since charging batteries "gas off" some hydrogen and oxygen when they're nearing full charge, various caps have been designed to catalytically recombine the gases to water (HydroCaps, for instance), or simply to condense evaporating water (like these), in systems that don't heavily overcharge. This technology was originally used in WWII submarines which surfaced to quickly diesel-charge their batteries and generated lots of explosive gases in the process.

We also used a device designed for the military called a "desulfator" (above). It uses a tiny bit of battery power to send a small high-frequency pulse back into the batteries, hampering the growth of large lead sulfate crystals that build up on the lead plates, eventually leading to premature battery failure. This rather cramped photo shows the 2" by 2" device.

Our previous home used both wind and solar electricity, while the current house is solely solar powered. While solar's up-front cost may be the highest of the available alternatives in terms of cost per watt produced, it's the simplest to install, the longest lasting, and the easiest and cheapest to maintain. Plus, our current site is ideal for solar but not the others, and you have to use what your site dictates! **Above is a shot of our only electric power source: about 1500 watts of solar power** by Kyocera, one of the oldest ceramics companies (and they aren't owned by an oil company!). We upgraded to 1500+ watts of solar (in the previous photo, plus one not shown) in order to charge an electric car conversion of a 1979 Porsche 924 more quickly. To see the technical specifications on these panels, just **Click Here**.

While our current array of PV panels runs the power of 10 panels directly to an Outback MPPT Controller (more on this later), and runs the output of 2 panels directly to our shed to charge our electric trikes, electric garden tractor, etc., our previous array (above) had switchable panels. Seen from the back of the panels, the center three panels were switched to either power the house in a nominal 12-volt (parallel wiring) configuration, or to charge our G.E. Electrak garden tractor, our cordless electric mower and string trimmer, or our electric-human hybrid trikes (seen on the **Transportation Option** page) using a nominal 36-volt set-up, with the panels wired in series. When we added panels the simple galvanized pipe rack had to be rebuilt to handle more weight and with added space. The part of the rack directly mounting the panels was then built entirely from 2-inch magnesium square stock, recycled locally from a commercial greenhouse frame.



This is a close-up of the switch arrangement used at that time, with the weather cover open. Each toggle controlled one panel using a Double-Pole, Center-Off, 20-Amp DC switch. Toggling up ran the three 12-Volt panels in series to run 36-Volt power to the electric tractor and electric-assisted trike. Toggling down put the panels in parallel to run 12-Volt power to the house. This switch box has been converted to allow the “extra” two panels, that normally run to our shed, to send power directly into the house batteries during winter. This has now been simplified to use a single switch.

Before flowing into the batteries the solar power gets intercepted by this device, a lightning arrestor. It connects to both the positive and negative wires, and shorts to a ground cable if voltage spikes too high.

The next item in the positive wire used to be a simple diode on a heat sink. This one-way electrical valve prevents energy from flowing outward from the batteries to the solar panels at night. This was omitted when we installed charge controllers, including the current Outback FlexMax-80, which replaces its function (see further below).

Then the power flows into this **DC electrical service box**. The left breaker cuts off the batteries. The next controls our present Load Diversion Controller (an Outback FM-80, seen below). The next controls the solar input. And the final two run the two DC load circuits in our house. **We don't use a non-renewable generator for backup power** and didn't do so in our previous home either. The battery is sized to ensure at least a 2-week supply of electrical power with no solar input. On the worst cloudy days, we still get one-tenth normal power input and an average of half of our days are cloudy. So designing with these factors in mind, we normally have far too much power. **To see a free Adobe PDF file of our household loads, just click:** http://www.geopathfinder.com/ElectricalLoads2010.pdf.

Above is an amp-hour meter. It functions as a battery fuel gauge. Even though it consumes a tiny bit of power, and injects a high-pitched, electrical noise frequency into the batteries, it's still worth its cost (about $200) for peace of mind, especially when you're just starting out in renewables and don't yet have a handle on your power usage vs. input.

Most solar controllers shut the PV input off when the batteries are fully charged, or, if you are Grid-connected, excess power is sent into the Grid during sunny days and purchased back from non-renewable sources at night. Instead, we had been using a load diversion controller (Trace C-30) which channels excess power into an "off the shelf" hot water heater and a small chest-type refrigerator. **Refrigeration isn't a huge priority in our home since we're not meat or dairy eaters**. Still, we do occasionally have left-overs or home-canned condiments that need cooling.

Above was our next load diversion controller. It used PWM, or Pulse-Width Modulation, to divert the exact amount of excessive input power that keeps the batteries at a specified bulk-charge or float-charge voltage. But with precision came a nasty low-pitched electrical hum from the pulsed DC current sent to the diversion loads. Eventually this had to go in favor of the older C-30 (black box above), and the house was quieter both in terms of sound and electric fields.

Both of these devices have been replaced by a controller from Outback, the FlaxMax-80. It replaces all of the functions of a reverse-flow-preventing diode (seen above), a load diversion controller (like the Trace C-30), and a PWM input controller (like the Trace C-40). It can handle up to 80 amps of power into 12-volt batteries, maximizing the power input from the PV panels, and has "AUX Send" output terminals to switch external power-control relays on or off at specific voltages. **This allows tight control over our power diversion loads, including the water heater, refrigerator, electric tractor, electric mower, electric hybrid trikes, an electric car, and electric oven.** Plus, this unit logs all of the voltage, amperage, and power statistics generated by the PV system, available for viewing up to 128 days later. And, since it can handle many different output voltages, it can be switched to charge both our 12-volt household battery bank as well as the 36-volt electric tractor battery and the electric car's three 48-volt packs. To see the manual on this product, just **Click Here**.

The photo above shows the little wood-covered, and heavily insulated, 15-gallon tank suspended behind the **masonry woodstove**, where water can be heated using a spiral of half-inch copper pipe around the stove's chimney or by the 12-volt electric heating element. The stainless steel, 12/24-volt heating element which we bought to replace the 120-volt element in the water heater can be purchased, among other sources, at **Backwoods Solar Electric Systems**.

Since neither the Trace C-30 nor the Outback FlexMax-80 is large enough to control the 32-37 Amps typically used by the water heater and refrigerator, we use two tiny 12-volt, 40-Amp relays to switch the power (one pictured above). Both are now activated by the auxiliary relay output on the Outback FM-80 controller. These relays divert excess solar into two very useful assets. Although the refrigerator can run using 120-volt AC or LP gas, we just use the 12-volt DC option, straight from the batteries and solar system. When the battery voltage exceeds 14.0 volts, the loads are on. When voltage drops to 12.8 volts, they turn off. This gives us a 30% "duty cycle" yielding cooled foods without freezing anything, and hot water without boiling it.

Our "critical" electrical devices (water pump, lighting, flour mill, radio) run directly from the batteries on 12-volt DC. Previously, our conventional 120-volt appliances run from this **Exeltech** **XP1100 Inverter** (above). Since humans are quite sensitive to AC electrical currents, the inverter is switched on only when AC loads are being operated. We use switched outlets at each appliance location and where a device uses a "black box" or "wall wart" to change voltage or switch from AC to DC current, we use additional labeled wall switches to activate only the intended device. This eliminates "phantom loads," energy sucking, unintended drains on an otherwise intentional, clean, and efficient electrical system.

This inverter easily handled all of our household loads (anything under 1100 watts, or about 9 amps of AC) **but was too small to use with our electric chainsaw or our electric car charger.** For these we could use the much larger (but cheaper, $717 on the Web) "modified-sine-wave" inverter (**Tripp-Lite APS3636VR**) mounted on our electric tractor, which can power two separate 15-amp AC circuits. Or we use the new 1800-watt Statpower (Xantrex) inverter (see below) that replaced the Exeltech. Now we can operate at least one full 15-amp AC circuit either indoor or outdoors.

Many homes that utilize RENEWABLE ENERGY for their electrical needs are wired for both low-voltage DC and standard AC loads. Since electric fields drop as voltage goes down, **12-volt lighting and appliances are an attractive option** where low-power, low-amperage devices can be used. In high-amp loads like big motors or water heaters, the increased magnetic fields can offset any gains made from lowering voltage, unless those loads are far from the main living spaces. In our home, all of the lighting is 12-volt DC, although we have a few 12-volt compact fluorescent lamps that convert 12 volts of DC to roughly 10,000 volts of AC in the bulb's "ballast". This creates a moderately-sized electric field "no-man's-land" around the fixtures as a trade-off for one-fifth the energy use. For more detail, check the **EMF Hazards** page.

Another factor that can reduce or eliminate AC electric/magnetic field exposure is the "sensible" use of an INVERTER in renewably-powered homes. If the home IS **NOT** connected to the GRID (by using a GRID-INTERTIE INVERTER), the "stand-alone" inverter turns low-voltage DC from storage batteries into "line-voltage" AC for standard appliances. **Since many AC loads can be eliminated by using DC devices wherever possible, the inverter often doesn't have to be running all of the time!** And if an inverter should break down (unlikely, but there's always a lightning strike!), **powering essential loads direct from battery DC is great insurance.**

Older and cheaper "square-wave" and "modified sine-wave" inverters rapidly and abruptly switch voltage levels to create a "choppy" sort of AC that only roughly approximates grid-produced AC. **The modern "sine-wave" inverter** produces a smoother, wave-like pattern of increasing and decreasing AC voltage that most electrical devices prefer. Not only do motors run cooler on sine waves, but the transformers found in many audio-visual devices and "wall warts" no longer hum. Sine-wave inverters *can* (at least with some modification) actually produce "cleaner" power than what's found on the grid. **Grid-produced AC often has voltage spikes, or dips (requiring the use of surge suppressors) and high-frequency "harmonics" (or**

"hash") and "transients" (or "spikes") that have additional negative health consequences.

But even the best sine-wave inverters also generate harmonic frequencies and internally-generated switching frequencies. What to do about it? Some inverters constantly check for switched-on loads and turn themselves on only when called for (the Search Mode). And in our home, each cluster of AC outlets has an inverter switch to turn the AC power on only when it's needed. Either way, **this eliminates inadvertent AC electric field exposure** since no AC is being sent through the wiring most of the time. **The Stetzerizer Filters I mention on the EMF Hazards page don't work well on some inverters.** A couple of inverters that seem to be unbothered by the capacitive filtration of the Stetzer filters are the Xantrex {Statpower} Pro-Sine series (seen on the previous page) and the Xantrex SW series.

Above is a Stetzer capacitive filter, composed of a small motor capacitor, a resistor to discharge the capacitor when it is unplugged, a couple of tabs to plug it in, and a plastic case. This one has been modified by adding an aluminum screen around it, shielding the home's occupants from high-frequency electric fields that radiate from the capacitor's outer shell. I've contacted the manufacturer about this problem (including electric field readings before and after alteration) and received no response, but this rig works well.

But by contacting your inverter's manufacturer, the technical staff may be able to build a frequency-targeted filter specifically designed to remove the unwanted frequencies the unit generates. We did this with a call to Exeltech for our XP1100 inverter. Above is what they sent. We wired it into the inverter's output and enclosed it in a metal box to shield its fields. The Exeltech sees the capacitor in a Graham-Stetzer filter as a challenge to put the voltage and amperage back in synch. This makes for a very unhappy inverter. The solution from Exeltech is lots of induction and very little capacitance. This creates a large localized magnetic field, so the filter they sent is enclosed in a heavy steel box that blocks most of the field. Our newer 1800-watt inverter allows us to use ordinary capacitive filters like the “Stetzerizer”.

And this is the final stop for AC current moving from the inverter filter to the AC loads. As you can see, we have only two AC circuits coming from our home inverter. One goes out to our shed where it powers chargers for an electric mower, our electric car, and a "string trimmer". It also powers a 0.5 HP irrigation pump for the garden and an electric rotary tiller for the garden (Mantis brand). Plus it powers various AC shop tools and AC lights, when needed.

So there you have it. What began as a single 20-watt, homemade solar panel built from surplus photovoltaic cells and the automotive battery in a 1971 VW Beetle eventually morphed into a moderately-sized but highly sophisticated energy harvesting system. No loans were applied for and no tax credits or government assistance were needed to very simply build our system as our needs/wants evolved through time. Obsolete parts were sold to others with appropriate needs and all of the wiring was done by a moderately skilled home handyman, gaining knowledge as the job required.