Office-Sized Solar-Electric System for Renters

Eric Grisen

Do you want to live with renewable energy, but don't think you can because you're renting? You can. With a little creativity, you can design and install a solar-electric system that has minimal impact on your rented house. We did!

This renewable energy system is big enough to power a home office, but it's small enough to live in a closet or travel in the back of a pickup truck.

Last year, my partner Tiffany and I turned on a 300 watt photovoltaic (PV) system to power my home office. We were able to install the system with minimal impact to our rented house—six lag screws into our patio's roof, and one hole into my office's ceiling. We also designed the system to be portable, so when we moved, we were able to pack it into our pickup truck in a matter of hours. You can build a system like this for less than US$4,000.

Our photovoltaic (PV) system powers the equipment I need for my telecommuting job at *Home Power*, including a Macintosh G3 desktop computer, Radius 21 inch CRT monitor, Aiwa boom box stereo, Umax Astra 2000U scanner, and an APS Pro 18 GB external hard drive.

Energy Efficiency First!

Before we installed the PV system, we applied lots of energy efficiency measures to our rented house. Why is that important? If part of your motivation is to have a lighter footprint on the planet, it makes sense (and cents) to reduce your energy consumption first. Inexpensive, even free, energy efficiency steps (like turning off appliances when you're not using them) result in a decreased daily energy requirement, and a smaller and less expensive PV system.

For example, by replacing our heat-producing, 100 watt, incandescent lights with cooler, compact fluorescents, we reduced our household lighting load by 70 percent. We further reduced our electrical load by turning our electric water heater way down, and wrapping it with an R-9 insulating blanket. Sensible energy conservation and modest consumption have always kept our utility bills relatively low. But in our all-electric suburban house that we were renting, we were unable to use less than 10 KWH a day on average.

Load Analysis

For our PV system to make sense to us, it had to be big enough to power all the loads in my office. If the system could cover my office's loads, it would give us to the flexibility to live off-grid, and I'd have enough electricity for my telecommuting work at *HP*. It would also be a good beginning to a home-sized system.

To find out how much energy all my computer equipment uses, I did a load analysis. Using a Brand Electronics digital power meter, I measured how many watts each appliance draws (see load table). I did this by plugging them into the meter, and then plugging the meter into the wall. The meter's kilowatt-hour (KWH) figure, recorded over a 24 hour period, allowed me to determine the average daily watt-hours used by each piece of equipment.

After I recorded the data from the individual loads, I gave myself a reality check by plugging the whole workstation's plug strip into the meter. This confirmed the individual measurements. My entire computer system uses about 1.3 KWH a day, or 6.5 KWH in a five-day work week. This is the amount of energy we wanted our PV system to cover.

The load table shows how I calculated how much energy my office uses. I learned this method from Solar Energy International (SEI). If you don't have a power meter, you can use the wattage information published on the appliance's label. But keep in mind that these figures represent the maximum draw of the appliance. Actual power requirements are typically lower, often substantially. By calculating or measuring exactly how many watts each appliance draws and multiplying it by how many hours a day it gets used, you can come up with a total daily kilowatt-hour number.

System Design

After the load analysis, we looked at other project considerations as we designed the system. The system had to be easy to move, have low impact on the house, and stay within our budget. It made sense for us to build the smallest system we could and then expand it later. After all, we do live on the grid. If the system can't keep up with my office usage, I can always plug into the wall for a little juice from the utility grid. We designed the system so that it would at least power my office's loads in the summertime.

Grisen System Loads

Load	W	× Hrs. / Day	× Days / Wk.	÷ 7 = Avg. Daily WH
Computer & monitor	149	10	5	1,064
Stereo	25	10	5	179
Scanner	17	1	5	12
External disk	13	1	5	9
Totals	204			1,264

The de-installation crew lowers the rack and PVs—Tiffany, Scott, Nicole, and Scott. We designed the system to be easily movable because when you move a lot, what goes up, must come down.

The system's loads.

Battery Sizing Computations

Avg. Daily WH	÷	Inverter Efficiency	÷	DC System Voltage	=	Avg. Daily AH
1,264		90%		12		117

Avg. Daily AH	x	Days of Autonomy	÷	Discharge Limit	÷	Battery AH Capacity	=	Batteries in Parallel
117		1		50%		105		2.2

DC Voltage	÷	Battery Voltage	=	Batteries in Series	x	Batteries in Parallel	=	Total Batteries
12		12		1.0		2.2		2.0

Seasonal Output Comparison

Season	PV Watts	x	Peak Sun Hrs.	x	System Efficiency	=	WH / Day
Summer (July)	300		7.7		65%		1,502
Winter (Dec.)	300		2.0		75%		450

I began crunching numbers to find out how many batteries the system would need. The data revealed that I'd need at least two of the 105 amp-hour (AH), absorbed glass mat (AGM) batteries that I wanted to use (see battery sizing table). Two of these batteries in this system provide a very modest amount of energy storage. But utility outages here in southern Oregon, are few and far in between. Also, I work during daylight hours most of the year, and have the utility grid available, so I really don't need too much battery capacity.

To figure out how many PV modules were needed, I did a little more math. The formula I learned at SEI suggested that I needed 3.39 of the PV modules I had decided to use. "Hmmm," we said to ourselves. "Can we afford to round up—three modules or four?" Well, we rounded down. Three modules were enough for us to start the system. PV is modular, so whenever funds allow we can easily add to it.

System Components

The PVs we chose are Siemens (now Shell Solar) SR100, 100 watt modules. These are nice, efficient, single-crystalline modules. They're stout, easy to work with, and they have cool silicon wafer polka dots. This particular model has since been discontinued, but at the time we were buying modules, they came to us at a good price.

We bought two of them with plans to buy another soon. Our plans to buy the third module were foiled when the *HP* crew gave us one wrapped up as a surfboard for a wedding present. I'm glad there was a PV inside that surfboard facade because it looked way too thick and klunky to ever carve any turns on a wave.

The other key component in the system is the sealed, lead-acid, maintenance free, absorbed glass mat (AGM) battery bank. I wanted these because they are OK to house inside living spaces, as long as the batteries' terminals are protected. AGMs don't have to be vented like flooded, lead-acid batteries. This means they can live in my office and I don't have to worry about explosive and corrosive gases.

I landed two, Concorde PVX-12105, 105 AH, AGM batteries, used, for next to nothing. They were still in good

System components: Class T fuse, shunt, batteries, meter, DC breakers, charge controller, and inverter with extension cords. Note the conduit (bottom left) that brought the PV wiring in from the roof.

condition—despite a traumatic past—so I snatched them up. In their previous life, they were part of a stand-alone PV system for *HP* Central's remote, off-grid radio telephone communication system. One day, some dishonorable scumbag stole the two, 75 watt PVs that charged this system. The batteries held up for a while, but eventually went dead from giving all their chemically stored energy to the repeater. After being removed, they were nursed back to life over several months. Now they're living a second life in our system.

The batteries, other system components, and breakers live in a wooden box Tiffany and I found at a junk store. Because all the components fit in or on the box, this half of the RE system can be moved easily with a hand truck.

On one side of the box, a Statpower ProSine 1000, 1,000 W inverter provides all the AC power my office will ever need, with significant room for expansion. My computer equipment likes its sine wave output. I like its easy-to-read digital display and two GFCI receptacles.

An RV Power Products Solar Boost 50 (SB50), 50 amp (A) charge controller, two DC-rated 30 A breakers in a Square D two-circuit box, and a Cruising Equipment E-Meter (now Xantrex Link-10) are mounted on the front of the wooden box. We chose the SB50 because we wanted a maximum power point tracking (MPPT) charge controller that we could grow into. The two breakers allow us to safely isolate any one current source in the system for maintenance, removal, transport—whatever. The E-Meter measures the amp-hour activity of the batteries. I like this meter because it tells me the system's status at a glance. I have it in scroll mode so I can see what's going on from across the room at my desk.

Installation Day

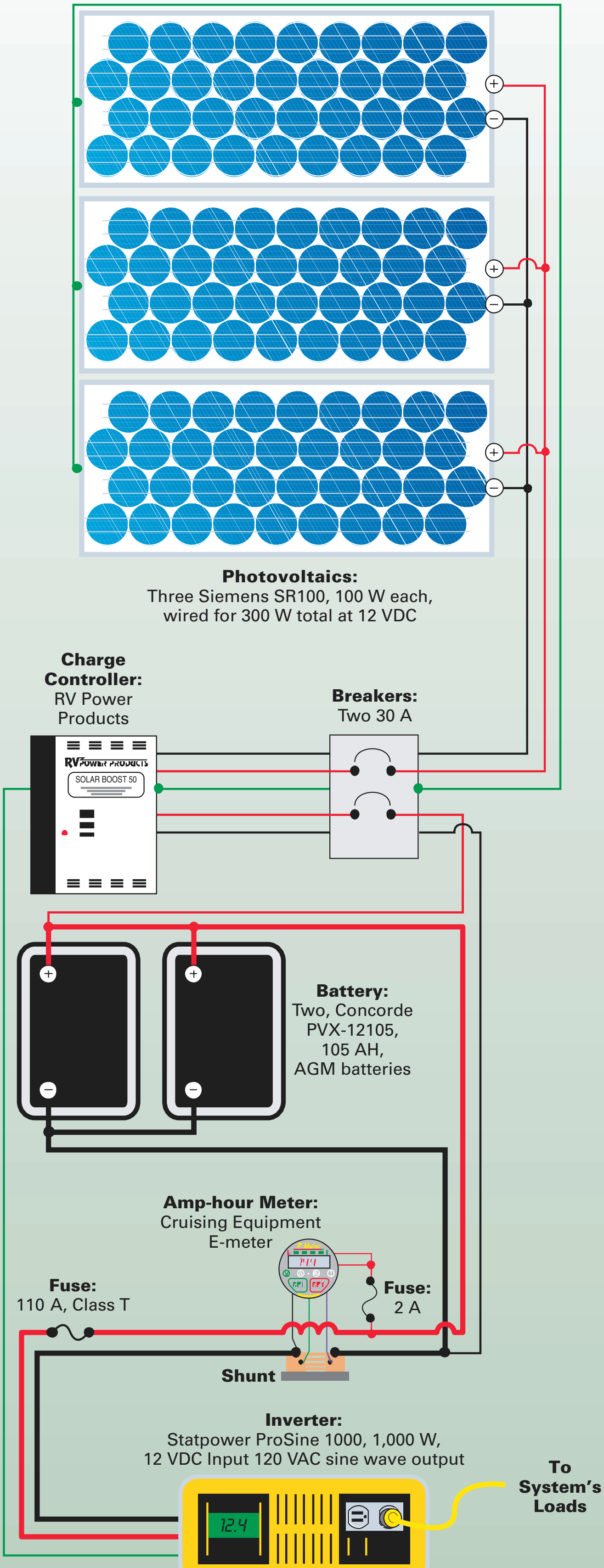
Before we installed the system, we had an impressive heap of renewable energy (RE) gear in the garage. It was pretty cool to look at, but the real fun began when we started to put it all together. I enlisted our friend Joe Schwartz to give me a hand. Start to finish, it only took us about six hours to install the system.

The first step was to install the PVs on the rack before we hoisted them up on the roof. We bolted them to the 1 1/8 inch (29 mm) galvanized, angle iron rack, using stainless steel hardware with lock washers. Then we wired the PVs up in parallel with #10 (5 mm^2) THWN-2 CU wire in Liquidtight conduit. We checked the module's short circuit current (Isc) and open circuit voltage (Voc) as we went to make sure the panels were working and wired properly. Then we climbed up on the roof to prep it for the array.

The patio roof is built with 4 by 4 posts and 2 by 4 rafters. The roofing material is translucent, corrugated, fiberglass sheets. These sheets are affixed to the 2 by 4s with 1 inch (25 mm) "wiggle molding" below and above. I laid down a few 2 by 12s on the wiggle molding so we could walk around on this fragile roof.

With the 2 by 12s providing a safe working surface, we lifted up the array. Lifting up the rack with the PVs installed was hard work, and a bit awkward. But once we got the

Grisen PV System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

Grisen System Costs

Item	Cost (US$)
3 Siemens SR100 modules, 100 W	$1,680
Xantrex ProSine 1000 inverter, 1,000 W	840
2 Concorde PVX-12105 batteries, 105 AH	408
SolarBoost 50 charge controller, 50 A	399
Cruising Equipment E-Meter	194
Cables, wire, conduit, J-box, disconnects	150
Steel & misc. hardware for PV mount	91
Trace TFB110 fuse, class T, 100 A	51
Shunt, 50 mV 500 A	25
Battery box, used	20
Total	$3,858

array up on the roof, we were glad we did all the wiring on the ground, because working space on the 2 by 12 planks was limited.

Next we positioned the array towards true south—that's about 18 degrees east of magnetic south in southern Oregon. Then we screwed the array down tight through the wiggle molding to the 2 by 4 rafters. We used six, 3 inch long, 3/8 inch (25 x 10 mm) lag screws to attach the array to the roof.

After the array was in place, we were ready to get the wiring into the house. The PV wires were run through Liquidtight conduit into the attic via an attic vent. To get the wire runs through the vent, all we had to do was pull a corner of the vent's metal screen back. Once in the attic, the wire runs entered a combiner box that transfers the PVs' output to a pair of #2 (33 mm^2) copper wires.

The #2 wire ran in conduit through the attic, and dropped through the ceiling into the closet in my office, where the rest of the system's components were located. At this junction, we had to drill a 1 3/8 inch (35 mm) hole for the conduit. *Don't tell our landlord—we patched it before we left. We think it was a minor thing to fix for installing the system safely.*

After the PV wiring was inside the office via conduit, we had to get the wires inside the wooden box that houses all the RE equipment. Using a 1 3/8 inch drill bit, we made a hole in the box for the conduit.

Before we started wiring up the DC breaker box, charge controller, inverter, and amp-hour meter, we popped the knockouts on the back side of each unit. Next we mounted the components onto the box, and marked where the knockout holes were. Then we drilled out the holes and permanently installed the components on the box. Each component has all its wiring concealed inside the box—it's safe, tight, and clean looking.

The PV wires were fed to a Square D breaker box that has two, 30 A breakers. The first breaker functions as a PV-to-controller disconnect and breaker. The second breaker is the controller-to-battery disconnect and breaker. These breakers' wire runs are made with #6 (13 mm^2) copper wires. After we had all the gear affixed to the box and connections made between PVs, breakers, and controller, it was time to work on the batteries.

We made the battery cables using #2/0 (67 mm^2) welding cable, lugs, and color-coded heatshrink tubing. This step requires a crimper, torch, vise, and solder. The nice thing about making the cables from scratch is that you end up with exactly what you want without unnecessarily long cables.

First the batteries were connected in parallel with short cables. Then the positive battery cable was connected to a Class T, 110 A fuse and the inverter. The negative battery cable was connected through a shunt to the inverter. Connections between the batteries and charge controller were made to the major positive and major negative. Connecting the battery cables to the inverter was convenient because the ProSine 1000 accepts battery connections from many angles. Once all the battery connections were made, we made the five connections for the amp-hour meter, fused it, and programmed it.

Six lag screws attached the PVs and homemade rack to the patio roof. After we de-installed the system (to move), we filled the holes with sealant and then put the screws back in.

System Performance

We've been really happy with the system's performance. It's functioning just as we expected without any glitches. We've lived with the system for over a year now. The loads and sizing figures have proven accurate. Our system delivers enough energy in the summer months to run my office

This hole we made in the ceiling for the conduit was the only interior impact our PV system had on the house.

full-time. In the winter, I use the grid about half the time (see seasonal output comparison table on page 28).

It's been an educational and empowering experience for us to run my office with solar electricity the past two summers. Although the system is modestly sized, we're very happy with it, and we'll be adding more PV to it. Our goal is to incorporate some of the components we have into a larger system that will cover all of our loads.

Sometimes we have surplus energy in our system. Tiffany and I have had a good time using up the surplus by having friends over to watch solar powered kayaking videos or to drink solar powered margaritas from the solar powered blender. As RE professional Bob-O Schultze says, "The only way you can waste renewable energy is to not use it."

Why did Tiffany and I choose a battery-based RE system over a utility-intertied system? We wanted to build a small system that we could take with us when we moved. Our setup guarantees that if we live off-grid, we'll have lights at night and I'll be able to work from a remote location. We also didn't want to make the wiring modifications to a rental that utility-interactive systems often require.

Go For It!

You don't have to own your own home or be wealthy to live with renewable energy. It's possible to install a PV system and still tread lightly on your rental with creative system design and installation. My advice to anyone who wants to live with a renewable energy system is to start by making your home as energy efficient as possible, and then go for it!

Access

Eric Grisen, *Home Power*, PO Box 520, Ashland, OR 97520 • 541-512-0201 • eric.grisen@homepower.com

Brand Electronics, 421 Hilton Rd., Whitefield, ME 04353 • 207-549-3401 • Fax: 207-549-4568 • info@brandelectronics.com • www.brandelectronics.com • Digital power meter

Concorde Battery Corp., 2009 San Bernardino Rd., West Covina, CA 91790 • 800-757-0303 or 626-813-1234 • Fax: 626-813-1235 • skipkoss@aol.com • www.concordebattery.com • AGM batteries

RV Power Products, 12598 Fortune Way, Suite K, Vista, CA 92083 • 800-493-7877 or 760-597-1642 • Fax: 760-597-1731 • info@rvpowerproducts.com • www.rvpowerproducts.com • MPPT charge controller

Shell Solar Industries (formerly Siemens Solar), 4650 Adohr Ln., Camarillo, CA 93011 • 800-272-6765 or 805-482-6800 • Fax: 805-388-6395 • solarsalesusa@shell.com • www.shell.com • PVs

Solar Energy International, P.O. Box 715, Carbondale, Colorado, USA 81623 • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org • Hands-on education

Xantrex Technology Inc., Distributed Power Markets, 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-2229 • dpm@xantrex.com • www.xantrex.com • Inverter, AH meter