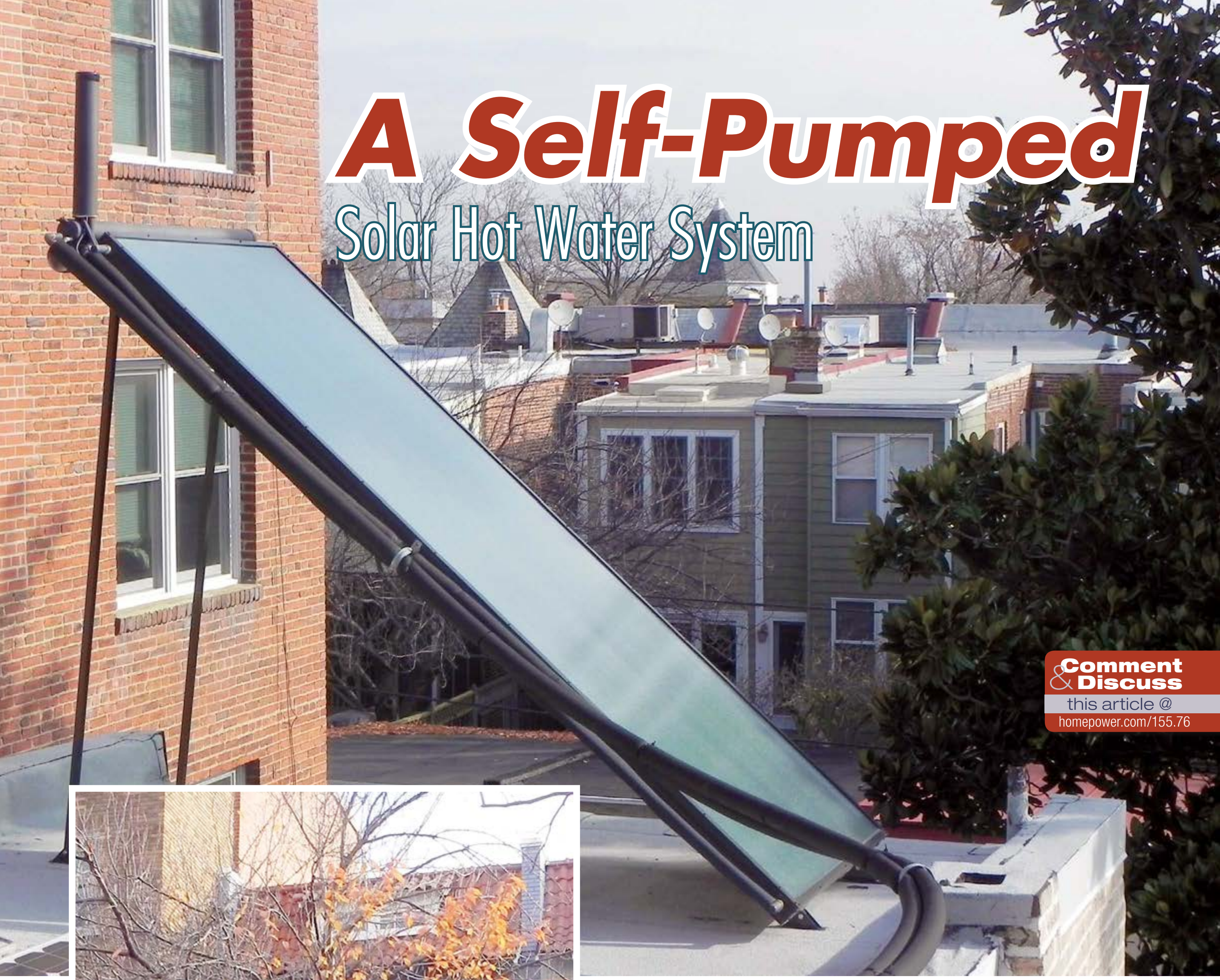
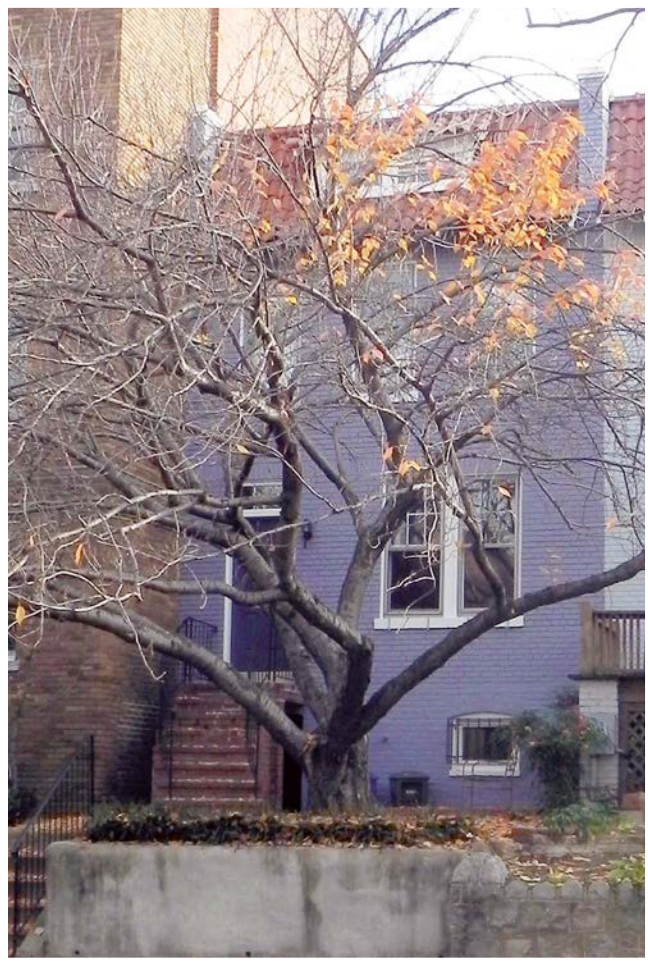
A Self-Pumped

Solar Hot Water System





Story & photos by Andy Kerr

Above: The PV array placement left room for a solar hot water collector. Note the vertical riser of the geyser pump, a characteristic of the Sunnovations system.

Left: Although this Washington, DC, townhouse has a fairly small, flat roof, it still accommodates both PV and SHW systems.

When my fiancée and I were ready to have a solar hot water (SHW) system installed at our Washington, DC, townhouse, I figured our only choice was to buy an active system that required mechanical valves and electronic controllers, and electricity to operate them. Of the four SHW systems I have owned, two were "active" (electrically pumped) systems and two were "passive" (self-pumped) systems, the latter with no moving parts. I prefer the latter because moving parts are subject to failure.

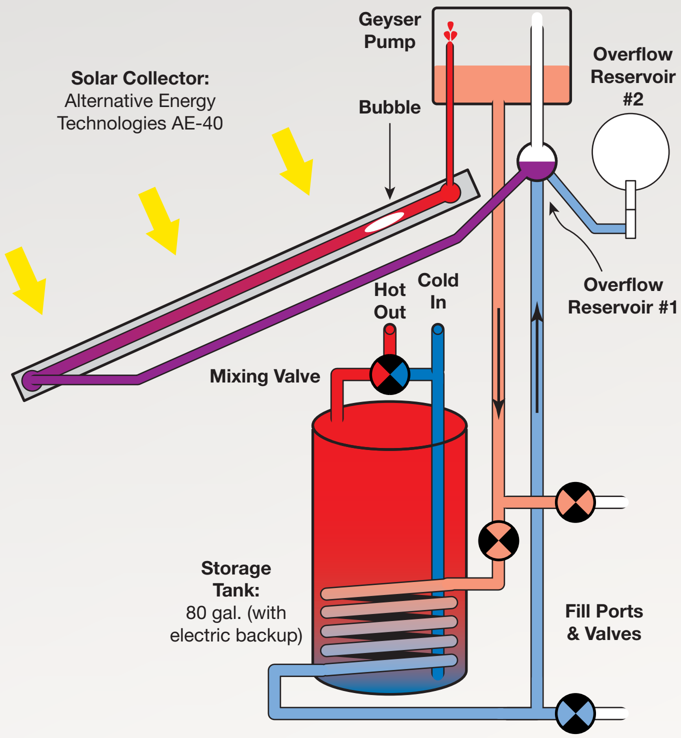
Then I ran across a start-up company—Sunnovations—touting its "geyser pump," which also has no moving parts. Sunnovations drew on—and then improved upon—the simultaneously famous and infamous Copper Cricket design—a passively (self-)pumped collector that was produced several decades ago (I was a satisfied owner of two of them).

Like most SHW systems of that era, the Copper Cricket was far from perfect. Despite its main advantage of having no moving parts, the Copper Cricket had two major shortcomings: it operated under a vacuum that could fail and frequently did; and it could overheat and "cook" the antifreeze solution that served as the heat-transfer fluid (HTF) between the collector and the storage tank.

Inset: This concept model has clear glass to view the geyser's pumping action.

Above: The vertical part is the geyser pump and the horizontal is the overflow reservoir, which prevents overheating of the heat-transfer fluid.

Geyser Pump SHW System



As in any solar hot water system schematic, the color shades between red and blue represent the relative temperatures of the heat transfer fluid (HTF) between hot and cold. The purple indicates the HTF that is preheated in Overflow Reservoir #1 by the condensing steam from the Geyser Pump.

Tech Specs

Overview

System type: Self-pumped closed-loop antifreeze

Location: Washington, DC

Solar resource: 4.6 average daily peak sun-hours

Production: 1,231 kBtu per month, average

Domestic hot water produced annually (estimated): 70%

Solar Equipment

Collector: Alternative Energy Technologies AE-40, 4 x 10 ft.

Collector installation: Roof-mounted, 45° tilt

Heat-transfer fluid: 45% propylene glycol & 55% water: rated to -22°F

Storage

Domestic hot water storage tank: Bradford White, 80 gal.; with electric backup

Performance Monitoring

Thermometer: Pasco, dial; maximum 240°F

Pressure gauge: Ashcroft, dial; range: 28 mm Hg (negative pressure) to 30 psi (positive pressure)

Pressure & temperature gauge: P&T dial gauge in brass well

A new Bradford White solar hot water storage tank also provides backup heating, saving space in an already-crowded basement.

A side view of the top of the tank showing the thermometer that measures the tank's output temperature (the nearest copper pipe riser). Above it is the Honeywell adjustable mixing valve. The pink electrical cable is the 240 VAC electricity for backup water heating. The two twisted pair wires in the background connect to unused sensors (for active, not passive, systems) in the Bradford White tank.

Determining Your Water Heater's Age

Water heater warranties range from three to 12 years and, typically, you get what you pay for. Longevity depends upon the tank lining, water quality, and other factors. Most people replace their water heater in a crisis, when they discover that its not producing hot water or is leaking. If your water heater is out of warranty, it is living on borrowed time.

How can you determine your tank's age? Check out its serial number, says *Home Energy* magazine. "If it begins A-83 or 0183, the tank was built in January 1983. B-83 or 0283 mean February 1983, and so on. If it begins 8301, the tank was built in the first week of 1983; 8352 would mean the last week of that year."

Solar-heated HTF coming into the storage tank (top gauge). The system pressure at the collectors ranges from 28 mm of mercury (vacuum) to 0 (ambient pressure) and depends on the insolation, ambient temperature, and temperature of the fluid returning from the heat exchanger. The gauge at the tank shows a higher pressure, as it includes head pressure (0.43 psi per vertical foot).

Sunnovations SHW systems are currently the only "self-pumped" systems certified by the industry-standard Solar Rating and Certification Corporation (SRCC). Sunnovations has obtained SRCC "OG-300" certifications for 41 system configurations, using combinations of five different collector brands, one- to three-collector arrays of varying-sized collectors, single and double storage tanks, and gas or electric backup heat.

The Sunnovations geyser pump depends upon a vacuum (negative pressure) to reduce the boiling point of the heat-transfer fluid to about 100°F. The "geyser pump," which relies on solar heat for its pumping action, is the heart of the system. It can be affixed to almost any collector. (The Copper Cricket was an all-in-one geyser pump and solar collector.) After an initial vacuum has been established, the pump circulates the HTF through the collectors. As the sun warms the geyser pump, pressure increases and the heated fluid flows.

Bright sun means higher operating temperatures and higher operating pressures. But even in full sun, the system operates at slightly below ambient (outside) atmospheric pressures. The maximum temperature the system may reach is 185°F, below the temperature at which the HTF breaks down. When the system pressure reaches the ambient pressure, a relief valve vents steam to a reservoir where it condenses back to liquid, and the geyser pump continues to operate. When the storage tank is fully heated, the return fluid to the collector will exceed 140°F, causing the pressure to rise rapidly. The temperature-limiting mechanism, which vents excess steam, cannot keep up, so fluid is vented out of the collector into the reservoir, thereby preventing the fluid from overheating. After the system cools, all the fluid expelled to the reservoir is drawn back into the system, which revitalizes the vacuum.

As the geyser pump system simply will not operate in extremely high temperatures, oxygen-barrier cross-linked high-density polyethylene (PEX) tubing can be used, rather than more expensive (materials and labor) copper pipe to carry the transfer fluid between the collector and the storage tank. PEX is flexible, so fewer joints are necessary and the joints are easier to make. While PEX piping can be problematic in traditional high-pressure and high-temperature active pumping SHW systems, as the Sunnovation system is self-limiting of both temperature and pressure, PEX is quite suitable.

While heated fluid flows without additional energy from electric pumps, for the passive Sunnovation system, the solar collector and geyser pump must be 33 feet or less above the storage tank. The geyser pump loses some heat to the outside air, especially on cold days. The unit must be warmed by the sun to 100°F to pump, so an active system set to come on at 90°F can be more productive on cold winter mornings. The relatively low flow rate (about 1 gallon per minute for two 4- by 8-foot collectors) will also result in some loss of heat delivered to the storage tank.

Several Thoughts

My system uses an 80-gallon Bradford White solar storage tank with built-in heat exchanger and dual 4,500-watt heating elements. The thermostat for the bottom heating element is located at midlevel on the tank, higher than the bottom heating element. The bottom element thermostat can be set to a significantly lower temperature than the top element thermostat, allowing adequate amounts of warmed—but not hot—water to be quickly heated by the top element when necessary, while also allowing cold water at the bottom of the tank to capture solar heat when available.

A major decision was whether to use gas or electricity to heat the water when sunshine is inadequate. We have a new super-efficient gas furnace—so efficient that it exhausts through an ABS plastic vent directly through the wall. Since there was no longer waste heat from the furnace to add to the natural gas water heater exhaust, water vapor could condense in the chimney and cause deterioration—a $1,200 flu liner would be needed. Using an electric storage tank eliminated the need for any chimney, so I removed the portion above the roof, which also occasionally shaded part of my PV array. The chimney below the roof found new life as a chase for the SHW system's PEX tubing.

During the estimated 20-year design life of any SHW system, the backup water heater may need to be replaced at least once—and maybe twice. The National Association of Home Builders says the life expectancy of a water heater is 10 to 13 years for gas and 14 years for electric. This replacement cost should be factored in when determining a SHW system's actual cost (see "Determining the Age of Your Water Heater" sidebar). If you replace your existing hot water tank when you install a SHW system, the new tank and installation labor qualify for the federal tax credit and perhaps other incentives. If your water heater is now beyond its warranty, it is living on borrowed time. When doing your analysis, the $1,000 to $1,500 cost to replace a conventional water heater should be subtracted from the cost of a SHW system, as it is a cost you would occur whether you have a SHW system or not. I estimated that the existing gas water heater would have had to be replaced in about six years anyway, so to determine the system's actual cost I deducted $750 from the gross system cost of the SHW system for a net cost of $1,780.

The chimney was removed and capped at roof level so it would not shade the PV modules.

The old flue is now the chase for the foam-insulated PEX tubing going to and from the SHW collector.

Navigating the SRCC Website

The Solar Rating and Certification Corporation (SRCC) is a nonprofit organization that publishes solar heating certification information online (solar-rating.org). Independent test laboratories, accredited by the SRCC, conduct a specified series of tests on collectors and systems and pass the information to the SRCC. SRCC certification is a requirement for the 30% residential solar tax credit and is required by many state, local, and utility incentive programs.

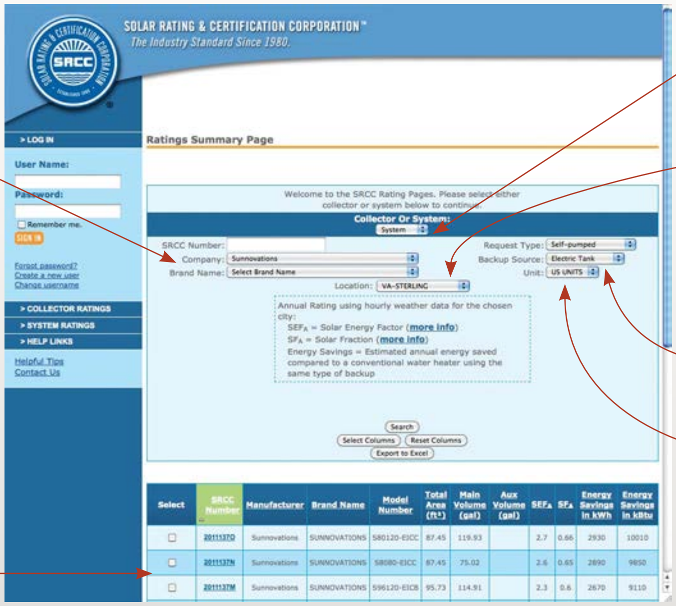
While the SRCC website has all the certification information, navigating it to find what you want can be intimidating. On the SRCC home page, pick Ratings from the left menu bar if you're looking for collector or system's certification status or estimated performance data. All of the other menu selections give information on certification rules, policies, and standards, and general information for manufacturers and interested users.

—Chuck Marken

If you would like to focus the selection for collectors, select the Company, Brand, Type, and/or Fluid. Leave blank and all of the collectors will be displayed.

Filling in the Company name and Brand will focus the search on only those systems; leaving it blank will display all systems.

The results of the search will appear below the search options as a summary. The energy savings shown (in kWh and kBtu) are exclusive for the Location that was chosen. Clicking on the SRCC system number will bring up the certification specifications and a system drawing in a two-page PDF file.



solar-rating.org

The default on the Ratings Summary Page is collectors—click on the box and select System for system ratings.

Selecting Systems will display new drop-down lists, including one labeled Location, which gives estimated performance that applies only to systems.

Note: Because they incorporate both collector and storage, ICS systems will only be listed in the system ratings.

If you would like to focus the selection, select the Type and Backup; if not, leave blank and all of the system types will be displayed.

Metric is the default units given; click and change to US UNITS if you want.

The system's cost was $8,500, against which we took a 30% federal income tax credit of $2,550; received a District of Columbia incentive of $1,700 (before taxes); and sold 10 years of future solar renewable energy credits (SRECs) for $1,780 (presently only DC and Maryland provide for SRECs from solar thermal systems).

This system has simple payback of eight years; a net present value of $2,220 for a 20-year investment horizon (the system should last at least that long); and a return on investment of 20%. If I had kept the natural gas backup heater rather than switching to electricity as a backup heat source, these results would be less attractive—that is, *if* gas prices continue record lows for the next two decades, which is not likely. If one also factors in the avoided cost of not having to spend $1,200 to line the flue to continue to use gas, my mostly solar-generated electricity looks as good financially when compared to buying gas.

An *Appraisal Journal* article found "an incremental home value of $10 to around $25 for every $1 reduction in annual fuel bills," so I estimate an increase in our home's value of between $2,600 and $6,500.

SHW System Comparison

System	Collector Area (Sq. Ft.)	Annual Energy Savings (kWh) Sterling, VA	Albuquerque, NM
Sunnovations geyser, Kioto (2 collectors)	43.7	2,030	2,880
Sunnovations geyser, AET (1 collector)	39.8	1,720	2,470
EagleSun, pumped, AET (1 collector)	39.8	2,120	3,130

The collector has quite a presence on the modest-sized townhouse's rooftop.

Performance

My system does not yet have an active monitoring system to be able to quantitatively track performance. However, I can share some observations. On sunny days, the HTF going into the storage tank is about 140°F. My summer gas consumption fell from an average of 6.6 therms per month to 0.6 therms (91% less), as it is now just used for cooking.

To get a quantitative sense of system efficiencies, it is useful to compare SRCC ratings for similar systems. The "SHW System Comparison" table (opposite page) depicts the best available approximations of three configurations: a Sunnovations geyser pump system with an AET collector; a geyser pump system with Kioto collectors; and a comparable active pump system with an AET collector.

While this SRCC OG-300 comparative analysis is interesting to technical types, it is not the most appropriate metric to evaluate SHW systems. Most interesting to the consumer is whole-system cost-effectiveness—measured in levelized dollars per kBtu—which is more appropriate, since it also factors in maintenance costs over the system's life. PEX rather than copper pipe means simpler and less expensive installation costs. No moving parts likely means fewer service calls. Lower—but hot enough—operation means no potential HTF overheating.

The Bottom Lines

I tend to have an early-adopter personality (not among the very first, but ahead of most everyone else), so it's no surprise that I chose to be one of the first to have a Sunnovations geyser pump when it came time to invest in an SHW system. Although its self-pumped system goes against the grain of current conventional SHW systems by operating at significantly lower temperatures and pressures, moving parts and electronics can fail, and I favor systems without them. I also don't like having to periodically change out "cooked" HTF.

I was willing to accept a lower total system performance for a passive, rather than active, system (see "Comparison" table). The production penalty (assuming we use every Btu of heat produced) for this particular system would be 19% less hot water than for a comparable active system. Given the significantly lower installation costs (PEX, etc.) and lower expected operating costs, the lower cost made the 19% production penalty worth it.

Now it turns out that the theoretical production penalty for using a Sunnovations passive system in my area (it varies based on the amount of annual insolation) need only be 4% for Washington, DC. Since our installation in December 2011, Kioto collectors are now available in North America. The Kioto collectors have a narrower riser diameter, which make them a more optimum fit with the Sunnovations geyser pump. They are also less expensive than AET collectors.

When one runs the numbers on these same three system configurations as if they were in Albuquerque, New Mexico (see table), it turns out the production penalty for my configuration over an the active system would be 21%. If the Sunnovation Kioto system were used, that penalty would be reduced to 8%.

Will the Sunnovation geyser pump go the distance? Did I make the right choice? I think I did, but only time, data, and experience will tell.

Access

Andy Kerr (andykerr@andykerr.net) is a frequent contributor to *Home Power* and a renewable energy and efficiency blogger (andykerr.net). He splits his time between Ashland, Oregon, and Washington, DC.

Resources:

Solar Rating and Certification Corporation (SRCC) • solar-rating.org

Sunnovations • sunnovations.org