

# KEEPING TABS ON YOUR PV SYSTEM

by Michael Brown

Until recently, consumers had few choices to help them keep tabs on their grid-tied PV systems. Most PV monitoring products were inverter-specific data loggers, which uploaded data to the manufacturer's Web portal. Homeowners had access to raw data—inverter energy production, simple alerts, and approximations of the CO<sub>2</sub> saved—but little more.

Now, monitoring products are providing deeper insight into PV performance and beyond—including whole-house energy management via energy generation and consumption monitoring. Newer monitoring systems can tell you how much money is saved on electric bills; report on whole building, branch circuit, and individual loads; and illustrate the effects of energy conservation steps taken.

The value of solar energy and energy conservation is best shown if their daily effects can be readily monitored. According to a February 2009 study by the Electric Power Research Institute, residential electricity usage feedback tools—such as monitoring devices—are effective at encouraging conservation. The study showed that using monitoring systems resulted in up to an 18% reduction in energy use, and that more direct, detailed information leads to higher levels of conservation. Being able to examine data can yield enough savings for the monitoring equipment to pay for itself—and more—over the life of the home.

"The future of residential PV in the United States is dramatically improving—playing a bigger role in the energy mix," says James Bickford of Tigo Energy, manufacturer of the Module Maximizer and its monitoring software. "The monitoring component will be a critical piece, allowing for control and management of distributed power sources and integration with the utilities."

There are many inverter and whole-house monitoring devices on the market—this article discusses hardware and software solutions that support monitoring of solar generation for residential systems.

## The Pitfalls of Data Communication

A big part of monitoring is getting the data where it needs to go. We can break data transfer into two parts of the communications process: from the solar equipment to the data logger, and from the data logger to the Internet.

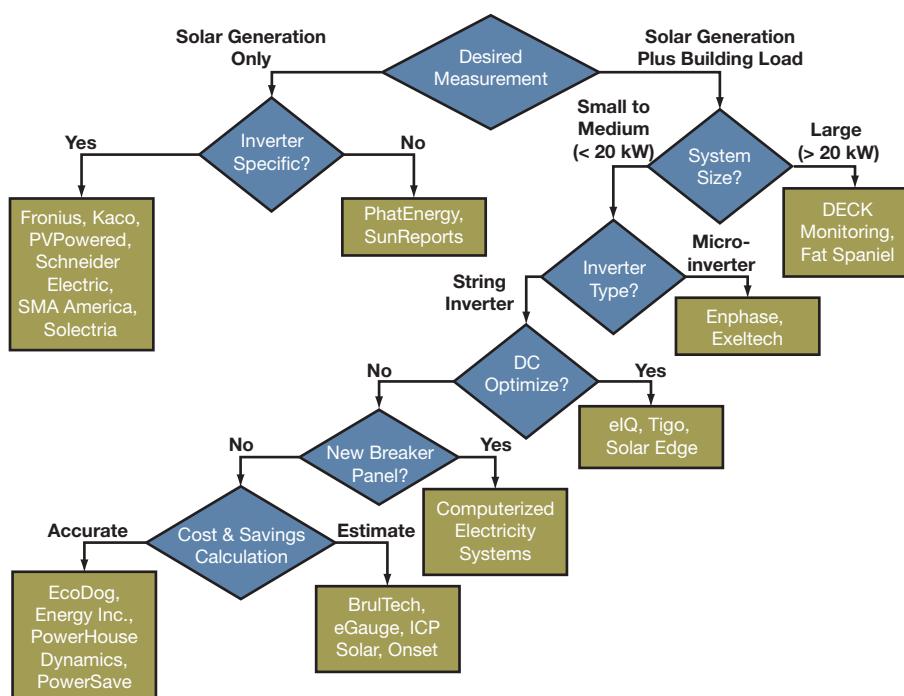
A cable is the simplest means of getting the data from the solar

equipment to the data logger—but running cables can be difficult or impossible due to the paths across land, in trenches, through walls, and in attics. This has driven the industry to introduce radio technologies such as wireless computer networking (WiFi); power line communications (PLC), which modulate data over AC lines; and radio technologies such as ZigBee, a wireless home area networks (WHAN) standard. These technologies have their own issues with distance, obstructions, and interference.

Moving the data from the logger to the Internet normally involves connecting with the homeowner's always-on Internet service, which is typically cable modem, DSL, or fiber optic network. Cat5 cables or WiFi are common but also share the above issues. Cellular routers allow for an upload strategy that's independent of the homeowner's service, but they can pose a significant one-time cost of about \$200, as well as ongoing monthly data service fees. The cellular industry has recently recognized the need for residential data service and more affordable service plans are available, from \$10 to \$40 a month.

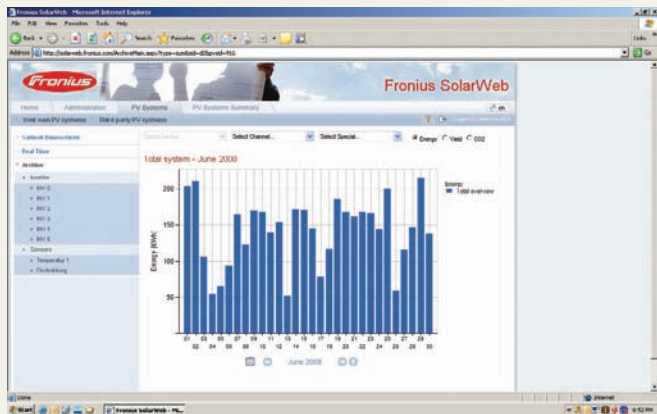
Careful review of the data communications requirements of the products, and assessing your situation, should lead to successful monitoring. Most products offer several options, so you'll need to research which data communication solution is best for your needs.

## CHOOSING A MONITORING SYSTEM

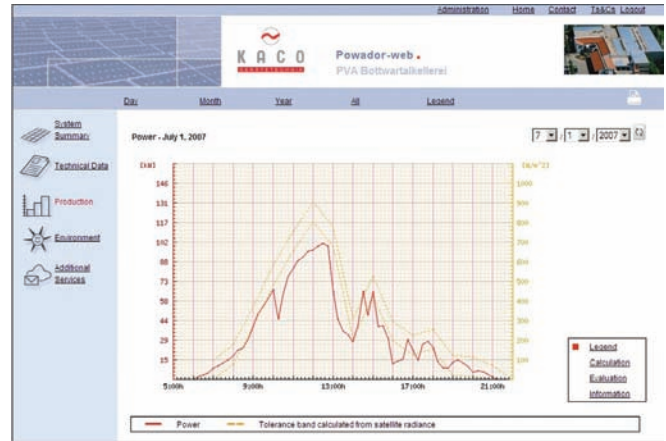


## Inverter-Tied Monitoring

Manufacturers of residential-sized inverters provide proprietary, basic monitoring equipment. There is little compatibility *between* different manufacturers' systems, but there is movement to standardize cables, wireless communications, and data protocols. Most inverter-paired monitoring systems offer data loggers that upload to the manufacturer's Web site, and some offer wireless displays that communicate over radio, such as Bluetooth. With wireless options, carefully evaluate the distances and obstacles to ensure a strong signal. Manufacturers' data monitoring systems include:



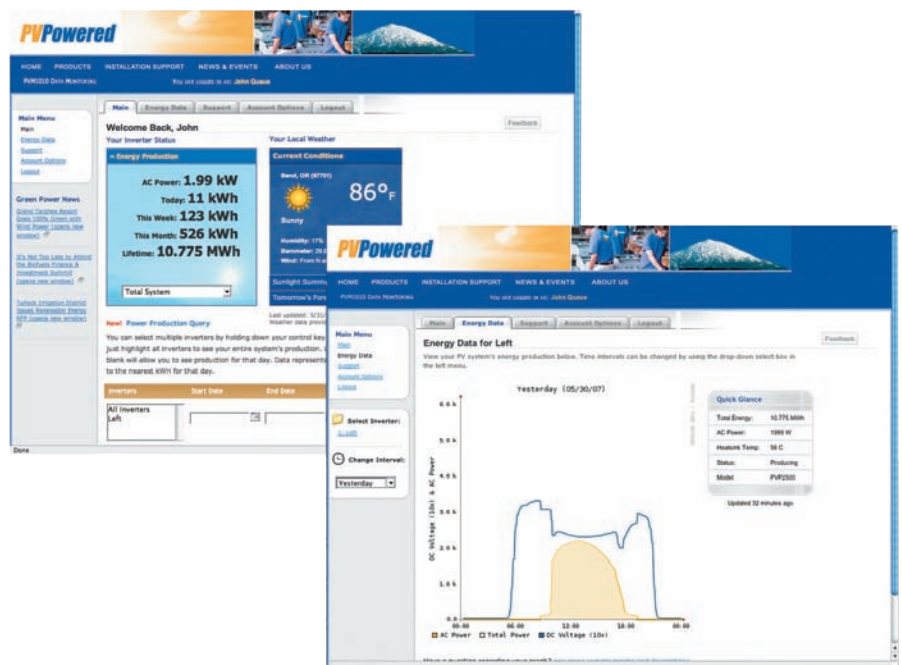
**FRONIUS** offers local PC data logging, analysis, and display; a weather station with multiple environmental sensors; and a wireless Personal Display. Data can be uploaded to their Solar.web site through a communications card and Data Logger Web device, which can be integrated with the Crestron home automation system. The wireless Personal Display uses a rechargeable battery that must be recharged and replaced periodically, or plugged into an AC outlet (becoming a small phantom load).



**KACO'S** watchDOG card's Ethernet port provides system data monitoring. This data drives both the blueplanet Web portal and the customizable inSIGHT wireless Internet, which displays system data via an RSS data feed—an online format used for delivering regularly updated content. Their proLOG device adds PC monitoring of multiple inverters, along with alarms and weather station sensors.



**PVPOWERED'S** PVM1010 module collects and uploads data to its www.mypvpower.com Web portal. Some inverter-independent monitoring systems, such as DECK monitoring, can connect to the PVM1010, and read the production and status data produced by the inverter. "The PVM1010 provides remote visibility to stakeholders in a system, enabling inverter system reports on system health, assisting the installer and manufacturer to provide a higher level of support," says Erick Petersen, vice president of sales and marketing at PVPowered.



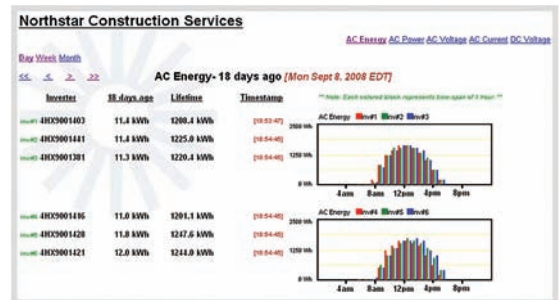
**SCHNEIDER ELECTRIC'S** RS-232 port provides for direct connection to a PC, and there are several third-party applications to collect and display the information. They also offer the GT Solar Inverter Monitor, which is wired to the inverter and is basically a remote version of the inverter faceplate meter. Slightly enhanced, it can show combined and separate information for up to five inverters. Their wireless gateway display can feed their Yahoo! widget via Ethernet or WiFi, but there is no Internet access to inverter data. Third party apps give you access to the raw data. I have a Schneider system and have built my own open-source solar monitoring application for it ([mike-land.com/Solar\\_Power/solar\\_power.html](http://mike-land.com/Solar_Power/solar_power.html)).



Schneider Electric's wireless gateway display.



The SolrenView gateway routes inverter data to the company's Web site.



**SOLECTRIA** offers sophisticated monitoring options, with subarray monitoring, revenue-grade (+/-0.2% or 0.5% accuracy, depending on the meter) power readings, and delivery of data to state agencies for monthly rebate-check calculation. Inverters are wired to the gateway, which uploads data to the SolrenView Web site. Building energy consumption monitoring and weather stations are optional add-ons.

## INVERTER-TIED MONITORING

Company	Product Name	Consumption Tracking	Modbus Devices	Weather Station
Fronius • <a href="http://www.fronius.com">www.fronius.com</a>	Personal Display, Solar.Web	N	N	Y
Kaco • <a href="http://www.kaco-newenergy.com">www.kaco-newenergy.com</a>	blueplanet (inverter); inSIGHT, proLOG, watchDOG (monitoring)	N	N	Y
PHAT Energy • <a href="http://www.phatenergy.com">www.phatenergy.com</a>	PHATlogger	N	N	Y, with Heliodyne
PVPowered • <a href="http://www.pvpowered.com">www.pvpowered.com</a>	PVM1010, mypvpower.com	N	Y	Y
Schneider Electric • <a href="http://www.schneider-electric.com">www.schneider-electric.com</a>	GT Solar Inverter Monitor, Gateway	N	N	Y
SMA America • <a href="http://www.sma-america.com">www.sma-america.com</a>	Sunny Web Box, Sunny Beam	N	N	Y
Solectria • <a href="http://www.solren.com">www.solren.com</a>	SolrenView, Gateway	Y	Y	Y
SunReports <a href="http://www.sunreports.com">www.sunreports.com</a>	Apollo1	N	Y, SHW, heat pumps, wind	N

**SMA AMERICA'S** Sunny WebBox collects and uploads data to the Sunny Portal Web site through a wired piggyback card installed in each inverter. Weather station sensors can be added to the Sunny WebBox. The company has recently re-engineered and reintroduced the Sunny Beam wireless device, switching from cordless-phone radio technology to a Bluetooth card in each inverter to improve the integrity of the signal. But I have found distance limitations on the signal strength when walls or ceilings are between the inverter and the Sunny Beam. An integrated solar cell can keep the monitor's battery charged.



The Sunny Beam Bluetooth-connected wireless display.

**SUNREPORTS** is unique in this list, as it is an independent company, but it collects solar production data through a direct connection to SMA America, Kaco, Fronius, or PVPowered inverters. This avoids the hassle of installing alternating current transformers (CTs) into the breaker panel as required by most inverter-independent monitoring products (see "Inverter Independent Monitor" section). Its product can also monitor solar hot water systems. Data is collected by the Apollo1 unit and sent via Ethernet to the customer's router. It can compare actual power generation against PVWatts or other software energy predictions.



Data Path to Internet	Accurate Financial Tracking	PC Display	Wireless Display	Web Site Display	iPhone App	Home Automation	Cost
Cat5 inverter to Data Logger Web, Cat5 to router	N	Y	Y	Y	N	Y	\$300-800
Cat5 cable from watchDog to router	N	Y	Y	Y	N	N	watchDog \$495; blueplanet from \$2,150; inSIGHT from \$195; proLOG from \$975
WiFi to router	N	N	N	Y	Soon	N	\$400-600
Cat5 cable from PVM1010 to router	N	N	N	mypvpower Web site	N	Y	\$399
Cat5 or WiFi from Gateway to router	N	3rd Party	Y	Yahoo! widget	N	N	GT Solar Inverter Monitor \$300; Gateway \$650
Piggyback card RS-485 to Web Box, Cat5 to router	N	Y	Y	Y	N	N	\$300-600
RS-485 from inverter to Gateway, Cat5 to router	N	N	N	Y	N	N	From \$450
Wired to source, Cat5 &/or PLC Apollo1 to router	N	N	N	Y	N	N	\$799

## Inverter-Independent Monitoring

Several monitoring solutions are inverter-independent. The basic technology is to use CTs in the homeowner’s circuit breaker panel to obtain data. One pair of CTs (for 240 V utility service) monitors the conductors from the inverter to a double-pole breaker to keep track of the home’s PV generation. Another pair reads the conductors from the utility meter to the main breaker to track net building load—the amount of energy that comes from the utility. More CTs can be used to monitor individual 120 V branch circuits for appliances or other loads, or in pairs for 240 V branch circuits, such as for air conditioners. With an array of CTs installed in the circuit breaker panel, the raw data can reflect a home’s full energy profile.

While this level of monitoring is powerful, installing CTs into a breaker panel presents some issues. First is jurisdiction approval and adherence to *National Electrical Code* standards. One issue is tapping into a branch circuit breaker—this enables the device to measure voltage and calculate power. Since this creates a small branch circuit inside the breaker panel, *NEC* Section 210.19 can apply. Some authorities also insist that the complete assembly of breaker panel and monitoring unit be UL-listed—an impossibility. UL Standard 1244 and 916 govern electrical monitoring devices, and vendors can choose to test and certify against one or both of these. Some permitting offices may be unfamiliar with this technology, so you may have to educate the staff on UL listing and *NEC* requirements that apply.

The second issue is physical space. CTs and the other equipment take up room in the typically already-crowded breaker panel. Locating additional equipment may necessitate mounting a suitable enclosure to the side of the breaker panel.

The third issue is data communication. Most CT-based systems transmit their data using PLC over the home’s power lines to a data logger. Signal integrity can be compromised by branch circuit length and “noisy” devices near the logger, such as computers, home electronics, or motorized appliances such as refrigerators, blenders, and air conditioning compressors—anything that causes radio frequency interference (RFI). Despite the challenges, most CT-based systems have few problems.

### Independent Options

Given the many options, how can you determine the best choice for your system? One differentiating factor is the device’s ability to either estimate the savings and costs of PV generation and building consumption, or to accurately calculate it given the homeowner’s utility rate schedule. Estimation based on a single approximate energy cost per kWh offers only a rough view of system performance, while accurate calculations allow the homeowner to do real analysis of generation and conservation effects on their actual utility charges.

## INVERTER-INDEPENDENT MONITORING

Company	Product	Consumption Tracking	Thermal Tracking	In Breaker Panel	Inverter-Direct	Modbus Devices
<b>Also Energy</b> • <a href="http://www.alsoenergy.com">www.alsoenergy.com</a>	PowerTrack, PowerLobby	Y, Net & branch circuit	Y	Y	SMA, Modbus	Y
<b>BrulTech</b> • <a href="http://www.etherbee.com">www.etherbee.com</a>	ECM-1240	Y, Net & branch circuit	N	Y	N	N
<b>Computerized Electricity Systems</b> • <a href="http://www.c-e-systems.com">www.c-e-systems.com</a>	Smart Distribution Panel	Y, Net & branch circuit	N	Replaces panel	N	N
<b>DECK Monitoring</b> • <a href="http://www.deckmonitoring.com">www.deckmonitoring.com</a>	Residential Core Package	Y, Net & branch circuit	Y	Y	SMA, PVPowered	Y
<b>EcoDog Inc.</b> • <a href="http://www.ecodoginc.com">www.ecodoginc.com</a>	FIDO	Y, 16 branch circuits, max. 64 boxes x 16 CTs	Y	Y	N	N
<b>eGauge</b> • <a href="http://www.egauge.net">www.egauge.net</a>	eGauge	Y (1), Net (2) & up to 9 branch circuits	N	Y	N	N
<b>Energy Inc.</b> • <a href="http://www.theenergydetective.com">www.theenergydetective.com</a>	TED 5000	Y	N	Y	N	N
<b>Fat Spaniel</b> • <a href="http://www.fatspaniel.com">www.fatspaniel.com</a>	Solar Splash	Y	Y	Y	Y	Y
<b>ICP Solar</b> • <a href="http://www.icpsolar.com">www.icpsolar.com</a>	GreenMeter	Y, 4 AC circuits	N	Y	N	N
<b>Onset</b> • <a href="http://www.onsetcomp.com">www.onsetcomp.com</a>	HOBO	Y	Y	Y	N	N
<b>PowerHouse Dynamics</b> • <a href="http://www.powerhousedynamics.com">www.powerhousedynamics.com</a>	eMonitor	Y, Net & 100 branch circuits; plus appliance transmitters	Y	Y	N	N
<b>PowerSave</b> • <a href="http://www.currentcost.net">www.currentcost.net</a>	ENVI	Y, Net & 9 branch circuits, plus appliance transmitters	N	Y	N	N

**ALSO ENERGY'S** PowerTrack device monitors solar-electric generation; whole-house and branch-circuit demand; and solar thermal systems; with accurate energy cost calculations (see "Independent Options" sidebar). It offers three models of weather station and can connect to SMA America inverters and any Modbus RS-485-compatible inverter (see below) and meter. The PowerLobby device is an option for performance display on a kiosk.



Modbus is an industrial-control data protocol that has been adopted by many commercial solar-monitoring devices, such as AC meters, weather stations, inverters (for status codes and power readings), and DC string current monitoring devices. RS-485 is a serial cable wire similar to the common RS-232 computer standard, but allows for up to 32 devices on a cable up to 4,000 feet long.



**BRULTECH RESEARCH'S** ECM-1240 collects and displays solar-electric generation values, and whole-house and branch-circuit demand numbers for net-usage reporting. It offers several communication options using the EngineP software to connect to a local PC, Web site, and Google's PowerMeter.

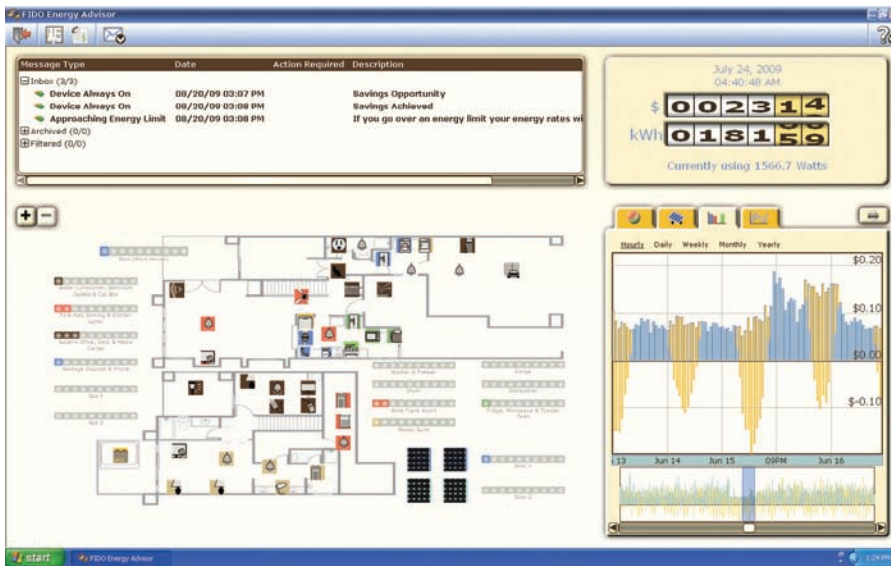
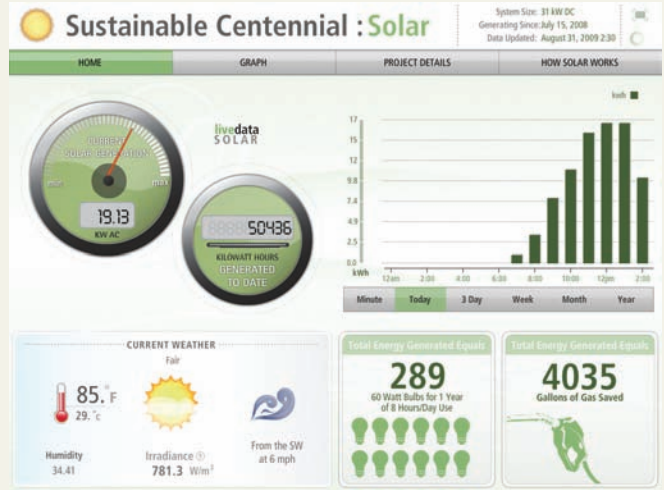
## COMPUTERIZED ELECTRICITY SYSTEMS (CES)

is unique in the market—its Smart Distribution Panel is an entire circuit breaker panel with built-in monitoring and automated switching/load balancing of 24 branch circuits. In addition to solar-electric system monitoring, it can integrate with wind and engine generators, smart meters, and smart appliances. CES offers a wireless display and a number of communication options to upload data to the Web site. The device also can communicate with home automation systems via its ZigBee interface.



Weather Station	Data Path	Accurate Financial Tracking	PC Display	Wireless Display	Web Site Display	iPhone App	Home Automation	Cost
Y	Cat5 to router	Y	N	N	Y	N	N	\$300–2,000
N	RS-232 or ZigBee–Gateway to PC or Cat5 adaptors to router	N	Y	N	Y & Google PowerMeter	N	Y	
N	Cat5, WiFi, ZigBee, PLC, GPRS options	Y	N	Y	Y	N	Y	\$1,500–3,000
Y	Cat5 to router	Y	Y	N	Y	N	N	\$700–2,000
N	PLC, serial/USB port to PC	Y	Y	N	N	N	N	\$1,000–1,700
N	PLC to HomePlug gateway	N	N	N, Archos tablet	Y, & Google PowerMeter	N	N	\$550–950
N	PLC to Gateway, Cat5 to router	Y	Y	Y	Y	Y	Y	\$200–400
Y	Cat5 to router, cell modem, satellite	Y	N	N	Y	3rd Party	Y	Installer sets price
Y	Cat5 to router	N	N	Y	Y	N	N	\$499.95; weather sensors approx. \$100 ea.
Y	Wired sensors to U30, Cat5 to router, WiFi or cellular	N	Y	N	Y	N	Y	Starting at \$675
N	WiFi to router	Y	N	N	Y	Y	Y	Starting at \$689
N	Wireless to Web Bridge, USB to PC, Cat5 to router	Y	Y	Y	Google PowerMeter	N	N	\$129–200

**DECK MONITORING'S** Residential Core Package is at the high end of residential monitoring. It offers revenue-grade meters, with PV generation, and whole-house and branch-circuit demand monitoring. It also directly connects to SMA America and PV Powered inverters, and any on-site Modbus devices. Accurate energy calculations, weather station sensors, and a Web interface round out the monitoring needs of large residential systems (20 kW and up).



**EcoDog's** FIDO system monitors energy generation and a nearly unlimited number of branch circuits for room-by-room monitoring of a building's energy consumption. Data is collected via PLC and displayed only on a local PC. The system generates recommendations for energy savings based on consumption patterns.

**EGAUGE** offers a low-cost solution for PV generation monitoring, with net and branch-circuit demand monitoring on up to 12 input channels. Data is sent over PLC to the homeowner's router. The company is working on a half-height enclosure for easier installation in the breaker panel. The device has a built-in Web server for local access, which displays the same highly detailed charts as the eGauge Web site to track energy generation and consumption. It also syncs with the Google PowerMeter Web site.

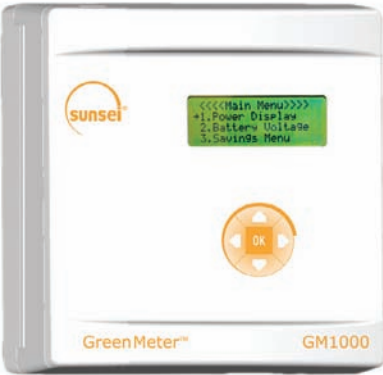


The Energy Detective reports real-time energy use.



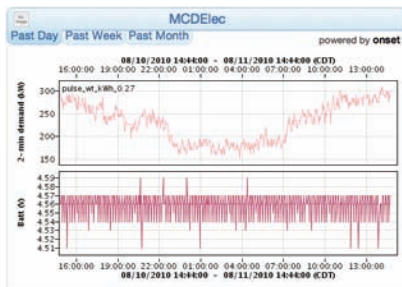
**ENERGY INC.** offers The Energy Detective (TED) 5000 that can monitor solar or wind generation, and whole-house or branch-circuit consumption. It can handle accurate utility energy calculations, displayed on a small wireless device, a local PC, the TED Web site, or the Google PowerMeter Web site. Several iPhone apps are available from third-party developers to sync with TED, allowing homeowners to keep tabs on their home from their phone.

**FAT SPANIEL** offers solar monitoring for small home systems to multi-megawatt systems. For the residential market, its Solar Splash offers inverter-direct connections to most inverters on the market, revenue-grade power meters for generation and consumption, weather stations, accurate energy calculations, and a custom iPhone app. The company recently exited the monitoring hardware market and has built a network of compatible hardware suppliers across the industry.



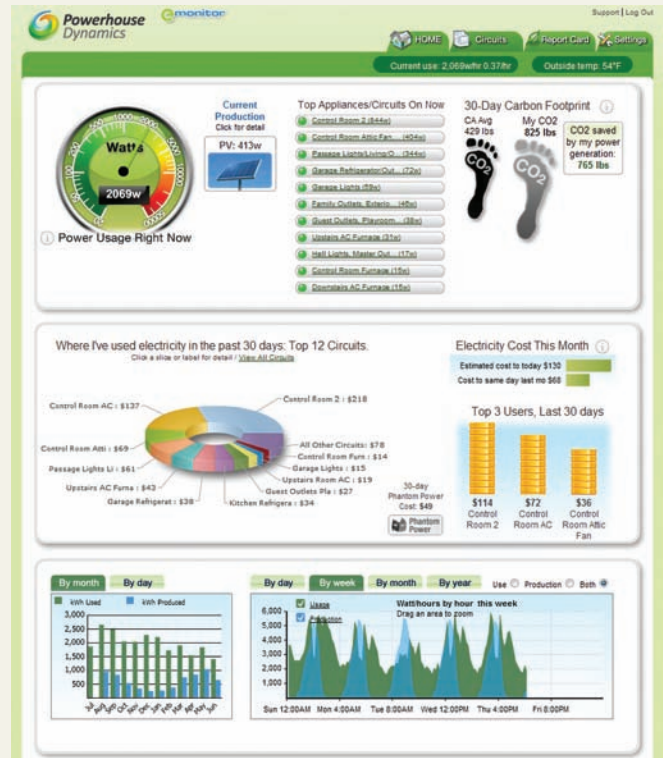
**ICP Solar's** wall-mounted energy logger and display.

**ICP SOLAR'S** GreenMeter offers monitoring on up to four DC and four AC circuits, handling multiple solar and wind, inverter, and branch circuits. It offers a weather station and a wall-mounted LCD display. The meter can also keep track of battery state of charge, such as amp-hours and amp-hours remaining. It also calculates greenhouse gas savings, cost savings, and revenue generation.



**ONSET'S** HOBO solar monitoring system is part of its overall data logging and monitoring product line. The U30 system can measure any number of DC or AC conductors for PV generation, as well as building net and branch circuits. A wide variety of weather station sensors can be added to the system. Data can be viewed on a local PC or the HOBOLink Web site.

**POWERHOUSE DYNAMICS'** eMonitor system measures solar generation, net building energy use, and up to 100 branch circuits. It can integrate with thermostats and other home automation systems. It offers a Web site and an iPhone app, with consumption alerts and recommendations.



**PowerSave's** monitor offers a graphical user interface.

**POWERSAVE'S** ENVI system measures up to nine solar, net demand, and branch circuits, along with optional appliance monitors. The system comes with a wireless display and feeds local PCs and the Google PowerMeter. Several third-party applications have been written to leverage the data collected by the ENVI—some are free, some are not.

## Module-Level Monitoring

PV systems can suffer from a range of energy-limiting problems, like module mismatch, partial shading, complex layouts, and subarrays on different roof planes. To address these issues, single-module AC and DC maximization technologies have been developed. Module-level monitoring is a beneficial side effect, and customers have taken a more active interest in their systems due to the level of information available.

Microinverters mimic the function of a string inverter, but for individual modules. Mounted on the racking system or the back of each module, a microinverter takes DC power from its partner module and produces AC power at its individual maximum power point (MPP), squeezing the most out of each module and, therefore, the maximum power out of the whole system. Microinverters allow more freedom of design since modules can be placed on different roof surfaces and angles, without degrading the overall power generation. Since there is intelligence built into each microinverter, the separate data can be collected and sent to a data logger. Data is normally transported from the microinverters to a logger via a PLC, removing the need for a separate data cable.

DC maximizers adjust the DC voltage and current for some or all of the modules in a string to generate more DC power than would have otherwise been available. With a standard string inverter, underperforming modules drag down the whole system's power production. DC maximizing allows for more freedom of design, since a roof with partial shading risk can have more modules installed than otherwise—partially shaded modules won't sabotage the whole system. Since it's difficult to transmit data over DC wiring, most DC maximizers use either a separate data wire or wireless communication with the data logger.

With both single-module technologies, data is uploaded through a gateway and the homeowner's Internet connection to the manufacturer's Web servers displaying a visual representation of system performance. These Web sites display individual module performance, with the module's graphic representation laid out in the same pattern as the physical modules. The module displays normally show a numerical and color indication of power—brighter colors indicate more power generation. Users can trigger a time-lapse display or move a slider back and forth, showing dawn-to-dusk performance. The color cue can help detect an

underperforming module or string, which could be due to shading, soiling, module mismatch, blown fuses, or broken wires. The installer can troubleshoot the system, armed with a great deal of information about the system's issues.

At this point, quantifying the actual *additional* power generated is difficult, since module-level monitoring is only available with microinverters and maximizers installed—you cannot see what the individual modules are producing without the distributed MPPT equipment. However, the non-quantifiable aspect of these systems—the benefits of module-level monitoring—should be taken into account in the overall decision process. Module-level equipment and monitoring systems include:

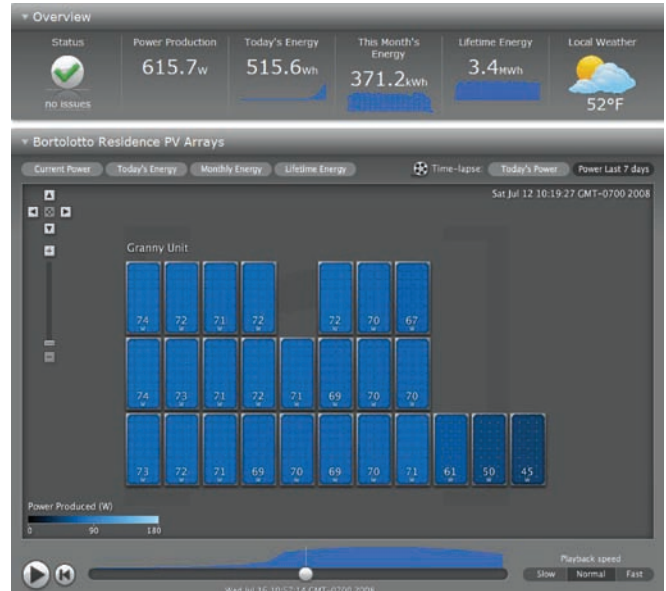
The screenshot shows a 'Data Monitoring Dashboard' for an 'eIQ' system. It features a 'vBoost Map' with a grid of 250 small circular indicators, each representing a module's power output. The indicators are color-coded from green (high power) to red (low power). Below the map is a line graph showing 'Power in Watts' over time, with a 'Playback Speed' slider and a date/time selector set to '3/14/2010 12:00:00 PM'. The dashboard also includes navigation links for 'Home', 'Support', and 'Contact Us'.

**eIQ** offers the Parallax DC vBoost 250 and 350 W converters, which can be installed on one or more PV modules in the system, as long as the power does not exceed the limit of the vBoost. For example, two 125 W modules could be connected to the vBoost 250, but monitoring would be for the pair, not for individual modules. The eIQ uses a parallel wiring architecture to generate constant voltage coming into the inverter, maximizing the inverter's MPPT system. The Monitoring System's Communications Module reads the module-level power information from each vBoost DC converter over the DC power line, avoiding an additional data cable or wireless radio system. It uploads to the manufacturer's Web site or can be downloaded for analysis on a local PC, and offers financial reporting and fault-detection alerts.

## MODULE-LEVEL MONITORING

Company	Product Name	Consumption Tracking	Technology	PV Tracking	Inverter Direct	Modbus
eIQ • www.eiqenergy.com	Parallax Monitoring System	N	DC maximizer	Y	N	N
Enphase • www.enphaseenergy.com	Envoy	N	AC microinverter	Y	N	N
Exeltech • www.exeltech.com	PVAC Module, HelioSentry	N	AC module	Y	N	N
Solar Edge • www.solaredge.com	PowerBox	N	DC maximizer & matching inverter	Y	Y	N
Tigo • www.tigoenergy.com	Module Maximizer	N	DC maximizer	Y	SMA	Y

**ENPHASE'S** Envoy device collects monitoring data from each microinverter over the AC power lines. The Envoy uploads to the Enlighten Web site where homeowners can view real-time or time-lapse historical data for each module. Alerts are sent if modules are not performing adequately compared to their neighbors. Enphase also has a "smart thermostat" called Environ which allows Enphase system owners to control their heating and cooling systems with an advanced thermostat.



**EXELTECH'S** AC module integrates an AC microinverter in the junction box on the back of each module. This saves the additional cable and installation time at the site, and lowers cost due to the high level of integration possible at the factory. The modules transmit data over the AC power lines to the HelioSentry device, which logs and uploads solar power generation and building load information to a local PC or for remote viewing with additional software.



The SolarEdge PowerBox and inverter.

**SOLAREGE** installs a PowerBox on each module, or includes it in the junction box, for controlling the DC voltage. The matching SolarEdge inverter is tuned to work best at a single DC voltage. Controlling both the generation and conversion of DC power can lead to production improvements of up to 25% compared to central inverter systems without distributed MPPT. The software automatically detects problems, issues status reports, alerts via e-mail, and provides recommendations and suggests solutions.

Weather Station	Data Path to Internet	Accurate Financial Tracking	PC Display	Wireless Display	Web Site Display	iPhone App	Home Automation	Cost
Y	Cat5, WiFi, satellite	Y	N	N	Y	N	N	Distributors set price
N	PLC to Envoy, Cat5 to router	N	N	N	Y	Y	N	Included; \$365 for Envoy; plus \$9/microinverter for 5 years of service
Y	WiFi to router	N	Y	Y	N	N	N	\$750
N	PLC to inverter, Cat5 to router	N	N	N	Y	Y	N	TBD
Y	ZigBee to MMU, Cat5 to router	N	N	N	Y	N	N	\$200 for 5 years; \$625 for MMU, plus \$350 for 5 years of service

## MODULE-LEVEL MONITORING, CONTINUED

**TIGO ENERGY** offers Module Maximizers, which attach to the frame corner on the back of each module. The Maximizer Management Unit (MMU) communicates bidirectionally with the Maximizers over a wireless network, adjusting DC variables to maximize the system's power. The MMU uploads data to the Tigo Web site via an Ethernet connection, with WiFi coming soon. Homeowners can review module-level DC power details. The MMU can be wired to SMA America, Fronius, and Kaco inverters to reflect the inverter's actual AC output power readings. Alerts are generated based on expected performance value setpoints.



## OTHER MONITORING SOLUTIONS

Solar installation companies are realizing the value of including or adding a monitoring system to their customers' projects. Monitoring adds significant value to help the customer understand whole-house energy management, and assists service departments in diagnosing any issues. A few of the larger installation companies' offerings are listed below:

**Akeena** uses Fat Spaniel's residential system (described above). **Lighthouse Solar** includes eGauge's system as its Lightgauge monitoring system. **PHAT Energy's** PHATLogger is an open hardware, software, and data platform that the company uses for its solar installations. It also plans to provide the device to the

monitoring market by the end of 2010. Currently, the device can collect data from SMA America and Solectria inverters. Data is uploaded via a WiFi connection to the customer's router. **PHAT Energy** plans to have an iPhone application by the end of 2010. **REC Solar** currently includes The Energy Detective's solar generation and building load-monitoring solution with each residential system. If the customer chooses to use Tigo's module maximizing system, then a Tigo monitoring system is installed instead. **SolarCity's** in-house SolarGuard system has a Web site and iPhone application for users, and is actively monitored for any underperformance. **SunPower's** in-house Monitoring System has a wireless in-home display, Web interface, and iPhone application.

**GOOGLE POWERMETER** makes a consumer's energy consumption data transparent and readily accessible from any Web connection. The goals? Heighten energy awareness and get consumers to take ownership of and reduce their energy usage. The PowerMeter allows users to track their energy use over time—by the day, week, or month—in a graphical format and to investigate phantom (always-on) loads, which are reflected by darker, shaded portions in the graphs. Consumers can also set their energy savings goals with the Budget Tracker and share their consumption (and reduction) information with family and friends. So far, availability is limited to certain partnering utilities and companies in the United States—SDG&E (San Diego), JEA (Florida), Current Cost, eGauge, and Energy Inc.



### Access

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