

Cast Study

MARIN COUNTY OFFICE ENERGY CONSERVATION, POWER PRODUCTION AND COST SAVINGS

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ABSTRACT

In 2003, Marin County took an important step towards its sustainability and energy conservation goals by installing an 89-kilowatt (kW) solar photovoltaic (PV) system on its General Services Building in San Rafael, California. After completing a competitive selection process, the county brought in Prevalent Power and RWE SCHOTT Solar Inc. (RSS), which together engineered a PV system that would zero the building's electricity bills and eliminate harmful emissions.

Using RSS' SunRoof FS™ flat-roof system, the companies engineered a non-penetrating mounting solution for the photovoltaic modules.

The PV system was designed to replace 92% of the building's energy* usage. Using a combination of net metering and time-of-use rates, the county will zero the building's annual energy bill even though they're not completely replacing its energy usage. The system was financed using a combination of rebates and low-interest state energy loans. Over its lifetime, the system will generate \$1.1 million in direct energy cost savings. The result is a system payback period of 12 years.

*For the purposes of this article, the generic term "energy" is used to refer to electrical energy.

This case study article provides an inside look at the PV engineering process, presents a set of best practices in PV system design and installation, and examines the economic and environmental rationale for purchasing the system.

MARIN COUNTY'S SUSTAINABILITY PROGRAM

The Marin County Sustainability Team is part of the Community Development Agency's Planning Department. The team's goal is to work with others to develop policies and programs that will help make the County of Marin healthy, vibrant and sustainable for many generations into the future. The team plays a key role coordinating and implementing the county's policies on climate protection, county operations review, energy efficiency, everyday sustainable practices, green building, green business, solar incentives, and sustainability in the county-wide plan.

Through its offices and website, Marin County offers up a host of energy savings tips, information and guidelines for residents of Marin County and anyone interested in energy efficiency and conservation programs. The county takes an active role in the community, promoting clean power and green building practices. The county's PV installation is the latest in the county's lead-by-example commitment to environmental-friendly projects and energy-savings programs.

RESPONSE TO AN ENERGY CRISIS

In response to the California energy crisis of 2001, Marin County began looking for opportunities to reduce its energy usage. The first site to be selected was the county's General Services Building next to the historic Frank Lloyd Wright-designed Civic Center. The building houses the garage, roads crew and radio shop. The county first did an analysis of its power consumption, then reduced its energy use through a series of projects to improve the building's insulation, lighting and ventilation systems. Next, it wanted to generate its own power.

Weighing the county's sustainability goals and green programs, the obvious choice was to implement a solar energy project. Several factors were critical in selecting solar over other distributed generation technologies:

- Photovoltaic power is 100% emissions free, an important aspect given the county's commitment to reducing carbon-dioxide and NO_x emissions;
- Photovoltaic power is completely silent, which was important because the building houses county workers and adjoins the site of a weekly farmer's market; and,
- A photovoltaic system would act as a highly visible example of Marin's commitment to renewable energy.

The General Services Building receives ample sunlight and is generally well suited for solar, with good southern orientation and minimal shading. The building features a flat roof that had been recently re-roofed using a continuous membrane product. A major concern at the start of the project was to minimize penetration of the roof surface (a major point of leakage) and to avoid violating the roofing company's warranty on the membrane.

The Marin County Sustainability Team, working with Tim Holmes of Kenwood Energy, initiated a competitive RFP process. Given information on the building's energy use, rate structure and footprint, bidders were asked to develop a complete system design to meet the following project objectives:

- Maximize the power and energy output without exceeding the facility's requirements;
- Ensure that roof penetrations would not void roof warranties or result in any leakage for the life of the roof;
- Allow the county to obtain all applicable state and utility loans and rebates;
- Create the greatest value as compared with the original investment; and,
- Include a real-time energy and power output display that could be placed in a public area within the Civic Center overlooking the PV installation.

The team received six proposals in response to the RFP. The winning bid was submitted by Prevalent Power, Inc. and RWE SCHOTT Solar for a flat roof solar energy system at an installed cost of \$304,079 after rebate.

ENERGY USAGE & COST ASSESSMENT

The first step in designing a solar power system is to assess on-site energy usage and to identify tariff elements that drive the customer’s power cost. This is critical to determine the “real” cost of power—the combined evaluation of all tariff elements. It is also critical that an accurate model of energy usage is developed so that decision-makers have a reliable projection of potential energy savings.

The county’s RFP provided a year’s worth of utility data on energy and demand for the facility. The building uses approximately 150,400 kilowatt-hours (kWh) per year with a peak monthly demand of 58 kilowatts (kW). The facility was on the local utility’s (PG&E) A10 seasonal demand metered rate. Under that rate structure, the county paid a seasonal rate for energy plus a demand charge based on the peak monthly demand on 30-minute intervals. The engineering team used a proprietary model to develop a snapshot of the facilities energy use and cost, as shown in Figure 1.

The figure shows monthly energy usage in kWh (solid bars) on the left axis. The solid and dashed lines show predicted and actual monthly energy costs on the A10 schedule on the right axis. The deviation be-

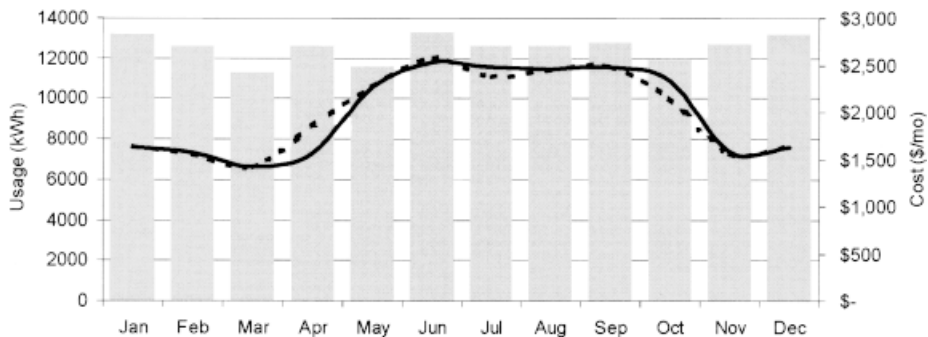


Figure 1. Energy Usage Assessment Without Solar on PG&E A-10 Rate

tween the two lines is the result of timing issues at the seasonal changeover from the winter rate to the summer rate. Overall, the model predicts the county's energy costs with less than 0.5% error.

The annual cost of energy for the building was \$24,007 for an average cost of \$0.16 per kWh. As Figure 1 clearly shows, the county pays a higher energy cost during the summer than in winter. A closer look at the A10 rate structure shows why:

- In summer, A10 users pay an energy charge of \$0.1595 per kWh plus a demand charge of \$6.70 per kW of peak demand.
- In winter, they pay \$0.1117 per kWh with a demand charge of just \$1.65 per kW.

The result of these tariff elements is that the county paid an average price of \$0.19 in summer and \$0.12 in winter per kWh of energy consumed.

The key conclusion is that reducing energy usage during summer months will have a disproportionate effect on energy costs because summer energy costs are higher. Because a solar photovoltaic system generates more power in the summer (because of the increase in available sunlight), it represents a unique opportunity to turn seasonal rate differentials to the customer's advantage. Plus, under California's net metering rules, energy users can export energy during the summer and "turn the meter backward," establishing a billing credit at the higher seasonal rates.

PV SYSTEM SIZING & ELECTRICAL ENGINEERING

PV system sizing is an iterative design process that seeks to maximize electrical generation and utility cost savings by:

- Fitting the PV system's seasonal output to the building's energy usage pattern;
- Evaluating the impact of a building's net energy usage on overall cost of energy under different rate scenarios; and,

- Developing an electrical and structural design suited to the building and specified equipment.

The process of sizing the solar power system generally focuses on four major variables: the amount of sunlight available (insolation), the seasonal variation in insolation, the target energy to be generated and the performance characteristics of the PV components. California requires utilities to provide net metering to solar power generators. Under net-metering rules, customers can export energy to the grid when they're generating in excess of their load. Without net metering, a solar power system's peak summertime output could not exceed daily summer usage. And, if energy usage is inconsistent or periodic, a customer would lose excess energy to the grid. Net metering solves all of these problems and allows the engineering team to focus on annual energy usage.

Rough System Sizing

For Marin, the engineering team initially focused on sizing the system to completely replace the building's usage of 150,400 kWh per year. The team then used 30 years of local insolation data to determine the solar resource on site. That data indicated that the building receives an average of 1,725 full sun-hours of insolation per year.

A sun-hour is defined as one hour's worth of full-intensity sun—which is defined as 1000 Watts per square meter at the Earth's surface. The reality is that at the start and end of the day, the available sun is much less than this. And often at solar noon, the insolation is a little higher than this. The annual insolation measurement is the sum-total of sun energy available on site.

To establish a starting point, the team divided the 150,400 kWh by 1,725 sun-hours to get a rough solar power system size of 87 kilowatts (peak AC power output). This represents the maximum target power of the system at the point of interconnection with the utility.

Savings Strategy & Rate Selection

The engineering team determined that the best savings opportunity was to somewhat undersize the system and switch the building to PG&E's A-6 time-of-use (TOU) metering schedule. A-6 is a non-demand-metered seasonal TOU schedule. That means the customer's bill is based on energy usage only and does not have a demand component. Energy was priced in three tiers: off-peak (nighttime), partial peak during morn-

ing and evening, and peak from noon to 6 PM. Peak rates range from \$0.3464 per kWh during summer to \$0.1711 in winter. By combining the A-6 rate with net metering, the system can take advantage of the differential pricing to favor the customer.

By sizing the system to export energy during the summer, the county is able to “sell high” and build up a credit that can then be drawn down during the winter, when rates are lower. The resulting price leverage actually enables the county to bring its annual net utility bills to zero while only generating about 92% of its actual energy needs. Figure 2 below demonstrates this dynamic. The conclusion from this exercise indicated an appropriate system sizing of 78.0 kW (AC peak power).

System Size Refinement

To refine this sizing, the team next had to determine what solar module and inverter would be used in the system. The module choice was in large part determined by the mounting system. Because the building featured a flat, single-membrane roof, an early system design decision was made to use RSS’ SunRoof FS mounting system, see Figure 3. The SunRoof FS flat-roof mounting system is a self-ballasting system that requires no roof penetrations. “Self-ballasting” simply means that the weight of the mounting system and the modules combined is sufficient to keep the solar array in place under wind and seismic loads. The SunRoof FS mounting system is engineered to support either the SAPC-165 module or ASE-300 series module. Because the residual load in the roof was lower than usual, the decision was made to go with the SAPC-165 because of its lighter weight.

The team also determined early on to use the Xantrex PV series grid-tie



Figure 2. Energy Savings Projection Using Net Metering and Time-of-Use Rates

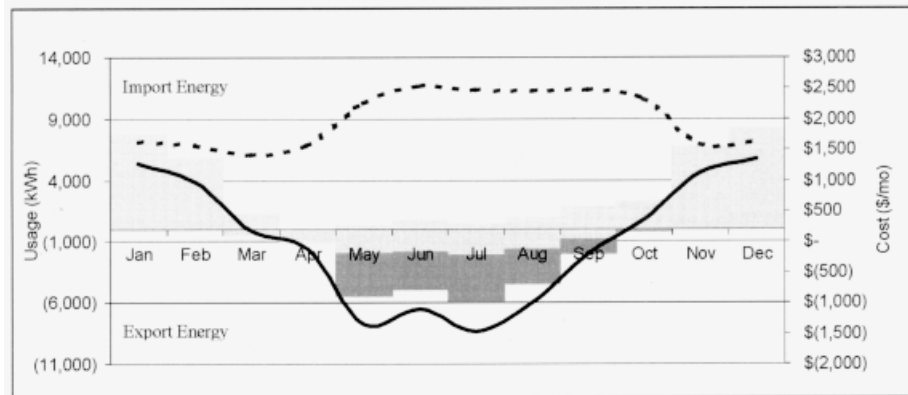


Figure 3. SunRoof FS Detail

inverter. This is largely because Xantrex's PV series is the dominant inverter manufacturer for systems of this size. The inverter has a peak efficiency of 96% converting DC power to AC power.

To get the needed DC array power (before conversion to AC), the AC power rating is divided by the inverter efficiency.

$$78.0 \text{ kW (AC)} \div 96\% = 81.3 \text{ kW (DC)}$$

The modules are rated at 165-Watts peak power under standard test conditions (STC). However, the team uses the PV USA test conditions (PTC) rating of 144.8-Watts per module. The inverter requires an input voltage between 300 and 600 volts DC power. To hit that input gate, the modules are wired in 12-module series circuits. That means the actual array has to be a 12-module multiple of the PTC rating. That results in either a 540-module array with a rating of 78.2 kW (DC) or a 552-module array of 79.9 kW (DC).

Final System Size

In the end, the 540-module array was selected for two reasons:

- The 540-module array fit better in the available roof area; and,
- The Xantrex inverters come in 30-kW, 45-kW, and 100-kW sizes. By choosing the smaller array, a combination of the 30-and 45-kW inverters could be used in place of the more expensive 100-kW model.

So, the final size was a 78.2-kW (DC) array. After inverter inefficiency, the system rates as a 75.1-kW (AC) peak power system at the point of interconnection. Under average insolation, the system is expected to generate 133,000 kWh per year. An analysis of the economic benefits indicates that the system will result in an annual utility bill of just \$1,000 vs. the previous \$24,000 per year expense. Figure 3 shows the final system output results.

SYSTEM MECHANICAL DESIGN

Following system sizing, the team completed the design phase by adapting the system's mechanical design to the site. The major engineering focus at this stage was on the mounting system and the "balance of system" components that interconnect the array, inverters and grid-connection.

Non-Penetrating, Flat Roof System

As was mentioned above, the team chose early in the process to use RSS' SunRoof FS flat-roof mounting system. This was to ensure that the roof warranty was not voided by the installation and that the system would not present any risk of leakage over its lifetime.

The SunRoof FS flat-roof system is a simple yet rugged mounting system made up of individual stainless and aluminum roof-jacks that lock into 3-module units, see Figure 4. When the entire array is assembled, the combined weight of the modules and roof jacks is sufficient to meet seismic and wind-uplift requirements. The system also has a unique feathering feature

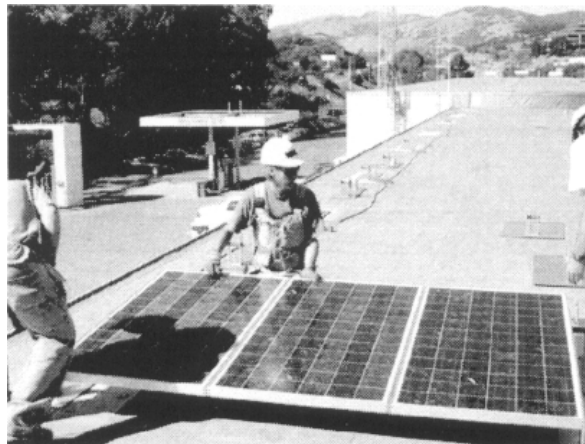


Figure 4: Installation of SunRoof FS

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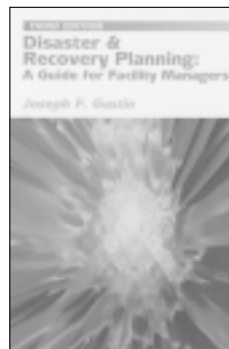
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that further reduces wind-uplift and has been wind-tunnel rated for use in up to 130-mph winds.

The SunRoof FS was chosen over other non-penetrating systems because the system:

- Features a 5-degree tilt to the south that improves power production and self-cleaning;
- Provides an air-circulation gap under the modules that improves their peak sun performance;
- Does not trap standing water on the roof surface as some foam-backed designs do; and,
- Enables easy access to the roof surface for inspection and repair. Removing a 3-module assembly requires the removal of just two bolts.

Balance of System: Lifetime Engineering

One aspect of photovoltaic system design that is often overlooked is the balance of system. The reality is that the overall system lifetime is limited by the weakest link in the entire design. Use of inappropriate materials or construction methods can compromise system lifetime. Because a solar power system purchase is typically rationalized using an expected lifetime of 25- to 30-years, the balance of system should be appropriately specified to meet that goal, as well as the requirements of National Electrical Code Section 690.

Another key reason to pay attention to the balance of system is to eliminate generation inefficiencies that result from wiring and corrosion problems.

Key specifications for a “best practices” in solar power system design should include the following:

Electrical:

- Wire terminations should be minimized to reduce points of electrical resistance;
- All circuits should be in metallic conduit, with the exception of intra-module wiring, which may be in free-air if USE-2 or equivalent wire is used;

- All electrical enclosures should be a minimum NEMA 3R (rain tight) rated or better;

Mechanical:

- Roof-mounted conduit should be mounted on UV resistant synthetic or metal standoffs;
- All structural metal components should preferably be stainless-steel or anodized aluminum;
- Where stainless is not practical, steel components should be electro-galvanized and all cuts should be treated with a galvanizing compound; and
- All mechanical fasteners should be stainless steel.

SYSTEM COST & FINANCING

The gross cost of the system was \$608,000. Total project costs are broken out below.

Project Cost Breakdown

System Cost	\$607,710
10% contingency set-aside	\$65,097
<u>Feasibility Study</u>	<u>\$35,000</u>
GROSS PROJECT COST	\$707,807

Project Financing

The system was financed using a rebate from the California Public Utilities Commission and low-interest loans from the California Energy Commission. RSS accepted assignment of the CPUC rebate so that the county's out of pocket cost was limited to the net cost.

GROSS PROJECT COST	\$707,807
CPUC Rebate	(\$353,904)
<u>CEC Loan</u>	<u>(\$232,510)</u>
NET COST TO MARIN COUNTY:	\$121,393

The project was completed in November 2003 and took less than 5 weeks construction time. The completed array and power center are shown in Figures 5 and 6.



Figure 5. Completed Array Looking North

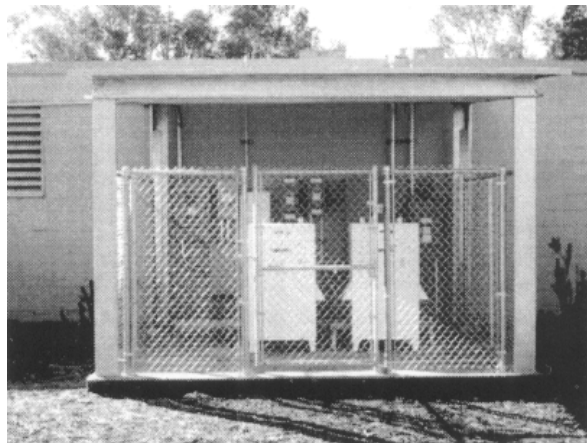


Figure 6. Completed Power Center

FINANCIAL PERFORMANCE

The low-interest loan (3.85%) Marin County received for this project from the California Energy Commission helped keep costs down. The system is expected to pay for itself in about 11 years, with loan payments that are roughly the same as the avoided energy cost. The internal rate of return (IRR) of the project is estimated at about 8% (see Figure 7). This is lower than the typical rate of return for a commercial project because the county is not able to take advantage of the tax credits and depreciation

benefits available to California businesses. However, because the county's borrowing rate was just 3.85% and energy bills represent a future sunk cost, the project is easily justified financially. Once the system has paid for itself, the money that was earmarked for loan payments can be applied to other public uses.

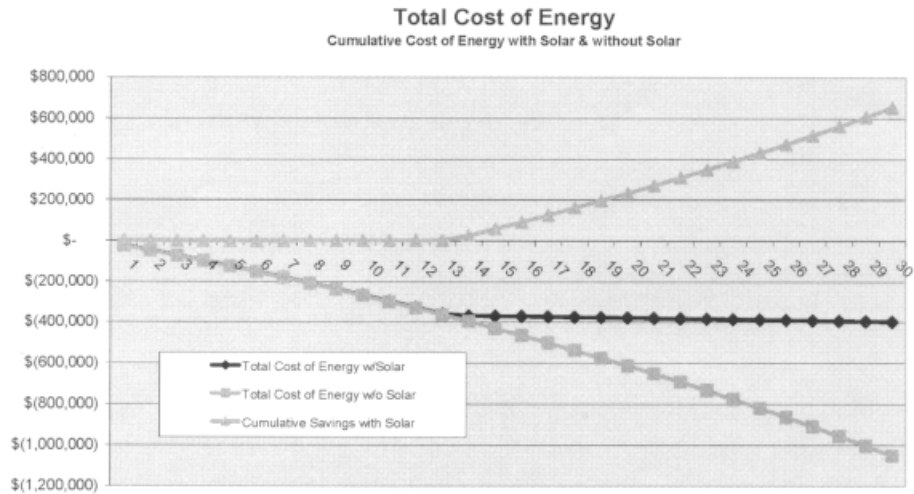


Figure 7. Project Cash Flow Projection (Payback in 11 Years)

ABOUT THE AUTHORS

Arno Harris is the Chief Executive Officer of Prevalent Power, Inc. Prevalent Power is one of California's fastest growing providers of large-scale solar power systems. Arno is an experienced executive and entrepreneur with a successful track record of building and growing innovative businesses. He is a founding member of two successful companies: RedEnvelope (NASDAQ:REDE) and Novo Media Group, Inc (sold to Bcom3). His background combines marketing, engineering, and consulting with experience servicing such clients as Toyota Motor Sales USA, GlaxoWellcome, MCI, Apple Computer, Hewlett-Packard, Nikon Precision, IKEA International, and NBC Digital Publishing. Arno is a published author, private pilot, and graduate of UC Berkeley. Mr. Harris may be reached at aharris@prevalentpower.com.

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