Photovoltaic Systems for Your Business

Producing electricity with an on-site photovoltaic (PV) system can have several benefits, including buffering your business from volatile energy costs, reducing your carbon footprint, and boosting your company's public image. Despite declining prices in recent years, PV remains an expensive option. Today, a commercial-scale PV array will cost a business on the order of $5 to $8 per watt of output power, including all subsystems and installation. This translates to roughly $0.20 to $0.30 per kilowatt-hour for the electricity produced. However, there are a number of rebates, tax breaks, and other incentives that can substantially reduce the cost of installing a system. Recent modifications to the U.S. federal tax code provide a 30 percent tax credit for and accelerated depreciation of investments in PV systems. Once installed, PV systems can operate for 30 years or more, although the power electronics will likely require periodic replacement.

What Are the Options?

A typical PV system contains two main components: the array and the inverter. The array is composed of numerous PV modules, each of which comprises many PV cells. The cells are made of a semiconducting material that converts incoming light energy into electricity. Although there are many emerging cell materials, those that are widely commercialized include single-crystal, polycrystalline, and thin-film silicon as well as thin-film cadmium telluride. An inverter is a power-conditioning device that converts the incoming direct-current (DC) power from the PV array into grid-compatible alternating-current (AC) power.

The remaining components of a PV system are collectively referred to as the balance of system (BOS), which includes the mounting structure, wiring, switches, and a metering apparatus that facilitates grid integration.

Each type of PV module has its benefits and drawbacks:

- *Single-crystal* technology has the highest conversion efficiency of any widely commercialized PV type—as high as 20 percent—but it also tends to be the most expensive.
- *Polycrystalline* technology is only about 13 to 15 percent efficient, so more panels are required to generate a given amount of energy, but this is mitigated by slightly lower costs.
- *Thin film* is the cheapest PV technology, but it also has the lowest efficiency—only about 5 to 11 percent. So for thin film, more modules, wiring, and installation labor are typically required to provide a given power output. However, advances in thin-film production have driven down costs to the point where this technology is becoming competitive with—and in some cases, cheaper than—others. Currently, there are three thin-film PV materials commercially available: amorphous silicon, cadmium telluride, and copper indium gallium selenide.

How to Make the Right Choice

For businesses planning to install PV systems, there are essentially three things to choose: the equipment itself, an installation contractor, and an array location.

Selecting Equipment

The task of specifying high-quality equipment has been simplified by organizations that subsidize PV systems, most notably the California Energy Commission (CEC).

Inverters. To make it onto the CEC's list of eligible inverters (www.gosolarcalifornia.org/equipment/inverter.php), individual models are required to pass Underwriters Laboratories' tests for safe operation and interconnection with the utility system, in addition to a battery of tests to evaluate performance under a variety of conditions likely to exist in the field. Inverter technology has improved to the point that manufacturers typically offer 10-year warranties on new units, and at least one company offers a 20-year warranty on its commercial-sized inverters.

Modules. When looking for high-quality PV modules, the CEC's current list of eligible photovoltaic modules (www.gosolarcalifornia.org/equipment/pvmodule.php) is a great place to start. Most utility rebate programs require that modules meet the CEC's requirements or other, similar standards. Today's PV modules typically carry a 20- to 25-year warranty, though an operating life of 30 years or more is not uncommon.

Selecting Qualified Installers

The demand for qualified installers has grown considerably in recent years as the demand for grid-connected PV systems has exploded. Many contractors have entered this field with little qualification or formal training in PV system design and installation, or in the relevant provisions of the National Electrical Code. This lack of PV-specific experience increases the possibility that inexperienced contractors will make design or installation errors that negatively affect system performance.

How can businesses gain assurance that the contractors they're working with know what they're doing? Proper training and a track record of successful installations are key elements in building confidence in contractor capabilities.

Since 2003, one ironclad indicator of contractor proficiency has been certification by the North American Board of Certified Energy Practitioners (NABCEP). This certification is awarded to PV installers who pass a rigorous exam developed with input from a broad swath of PV-industry stakeholders. NABCEP certification is widely recognized in the industry as the single most credible indicator (but not a guarantee) of contractor competency. As of late-2008, 639 contractors had received NABCEP certification (as listed in the NABCEP contractor database, www.nabcep.org/map.cfm), and that number is growing quickly. The web site Findsolar.com is another resource for finding local contractors and reviewing their certifications.

Selecting an Array Location

Though some businesses place PV arrays on parking-lot canopies or atop pole mounts, the majority are found on rooftops. Four important criteria to consider when selecting the location for commercial PV installations are the available solar resource, the condition of the existing roof, the size of the roof compared with the desired output of the system, and the presence of any objects that will shade the array.

Available solar resource. Solar resource refers to the average annual amount of sunlight that reaches a given site. The greater the solar resource, the more energy a particular PV array will generate. In general, in the U.S., the solar resource is higher in the South and Southwest (the "Sun Belt") than in New England or the Pacific Northwest. Because the feasibility of installing a PV system is closely linked with the amount of sunlight available, evaluating the solar resource at a given location is an important first step when considering a PV installation. One of the most powerful and simple tools to help with this type of site evaluation is a free online tool from the National Renewable Energy Laboratory called PV-Watts that allows you to quickly estimate system output throughout the year based on geographic location and system setup.

Condition of the existing roof. It's vital for businesses to be apprised of the condition of their roof prior to installing a PV array because the cost of repairs or a complete reroofing will be substantially greater once the array is in place. So if the existing roof is in poor condition, the time to address that problem is before the array is installed.

Size of rooftop and system output. A general rule of thumb is that for every kilowatt of peak power generated, you need about 100 square feet of installed panels, though this can vary depending on many factors, including climate, panel orientation, shading, type of module, and outdoor air temperature. Also, it is important to remember that in a commercial rooftop array, you'll often have to allow for space between parallel rows of panels, so that one row doesn't cast a shadow on the row behind it. Any contractor you work with should be able to analyze the site specifics to maximize wattage with the existing roof space.

Shading. When an individual module in an array is shaded, the array's power output will be reduced to a degree much greater than simply the proportion of the area that's shaded. This is because the current output of all modules connected in series is limited to the current output of the least productive (shaded) module in the series string. So if part or all of one module in the string is shaded, the power output of the remaining modules in the string will also be reduced. It's difficult to predict the actual amount of reduction because it depends not only on the pattern of shading, but also on the array layout (**Figure 1**).

The ideal situation is of course to select a location where the array will remain completely unshaded all day throughout the year. But this is often not possible because trees, neighboring buildings, rooftop equipment, or other objects will block sunlight at least some of the time. Contractors use specialized tools to assess the degree of shading a proposed array will experience throughout the year.

What's on the Horizon?

There are three critical forces that will affect the PV market significantly over the coming years: political developments, technological advances, and economic forces.

Policy drivers. In the U.S. and Canada, it's likely that in the next several years there will be national legislation that sets limits or reduction goals for greenhouse gas emissions. This could result in a surge of on-site renewable power generation in the commercial sector and a potential increase in system costs, if demand outstrips supply.

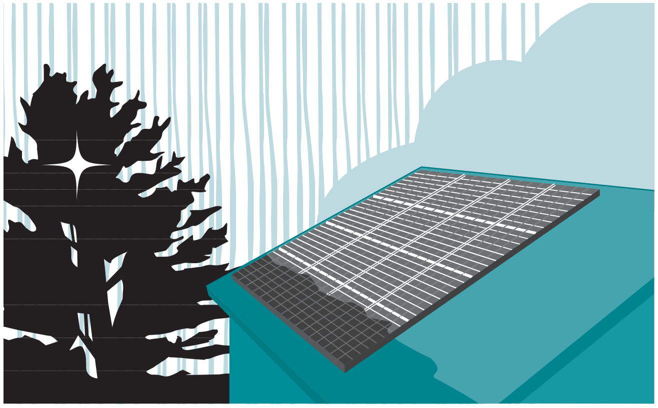
Tax incentives and rebates provide the most direct and responsive ways that government and utilities are helping to facilitate PV market growth. Currently, the U.S. federal government allows five-year depreciation of the cost of a PV system and a 30 percent investment tax credit with no cap. The North Carolina Solar Center's Database of State Incentives for Renewable Energy (www.dsireusa.org/) provides incentive information for any jurisdiction in the U.S.

Technical drivers. A global shortage of high-grade silicon that began in 2005 led to a construction boom of new polysilicon manufacturing facilities. But because these facilities take roughly three years to come on-line, and demand remained strong during that period, there was a temporary reversal to the decades-long trend of declining PV prices. As new facilities begin entering production in 2008 and beyond, there is now a possibility of an oversupply of modules, which could significantly depress prices. However, it is not yet clear whether this scenario will play out, or whether other forces will combine to keep supply in step with demand.

In recent years, research institutions and the solar industry have funneled millions of dollars into developing new thin-film technologies and production methods. Those

FIGURE 1: The effects of shading on PV systems

The influence of shading on the power output of a photovoltaic (PV) array depends on both the portion of the array that is shaded and the electrical layout of the modules. In this array, if the four modules in each column were wired together in series and those four columns were wired in parallel, then the output of all four series strings would be reduced because each string contains one shaded module. If, however, the array were designed so that modules in each row are connected in series and the rows are connected in parallel to the inverter, the output of the top three rows would be unaffected by shading—and more power would be delivered to the inverter.



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investments are beginning to pay off as thin-film technologies have made huge strides in efficiency, production volumes, and cost reduction. The extent to which thin film will affect the PV industry remains uncertain, though it will undoubtedly continue to gain market share because the design flexibility and plummeting costs will continue to appeal to many purchasers.

Economic drivers. Cost is the single largest barrier to widespread PV adoption. Except for the period of the global silicon shortage (which is now ending), PV costs have declined continuously as production volume has increased, and this trend is expected to continue. You can find an index of current and historic module prices at www.solarbuzz.com.