How PV Roofs Can Reduce Costs

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As energy costs continue to rise, building owners and facility managers look for alternate methods to generate energy and reduce costs. Installing photovoltaics (PVs) on roofs can generate electricity and reduce energy costs, as they are a source of renewable energy and enhance the sustainable features of the facility.

PV history and functionality

The first conventional photovoltaic cells were produced in the late 1950s and were primarily used to provide electrical power for earth-orbiting satellites and battery charging. This changed in the 1980s when they became a common power source for items such as watches, calculators and radios. After the energy crisis in the 1970s, PV power systems for residential and commercial uses experienced a surge. Presently, the PV industry is growing 25 percent a year in the U.S., Japan and Europe.

A PV cell is a semiconductor material that converts sunlight into electricity. It is manufactured with one side having surplus electrons (N Type) and the other side having a shortage (P Type). When sunlight strikes the PV cell, the electrons within the cell are energized and move, creating direct current flow. The cell will operate at maximum capacity during peak sun hours. For example, California typically has five hours of peak sun per day and Massachusetts has four hours (i.e., a 100-kilowatt system will produce 500 kilowatt hours during a five-hour peak period).

PV-generated electricity can be stored in batteries for future use, used directly by the building occupants or delivered to the grid (Figure 1). An inverter is needed to convert the direct current to an alternating current. A transformer then increases the voltage for power grid transmission. When delivered to the power grid, the utility meter runs backwards (called net metering) and the utility company pays for this electricity (rates vary by region and state). To date, 43 U.S. states, the District of Columbia and Puerto Rico have adopted net metering policies.

It's all in the details

Materials

Various types of semiconductor materials (silicone, cadium telluride and gallium arsenide) can be used for PV cells. Silicone is the most frequently used material for PVs and has two general types—crystalline and amorphous. Crystalline silicone, the most common type, is cut into thin wafers after being cut from a solid silicone. The silicone wafer has electrical conductors plated to each side and is placed between a front cover with low reflectance (i.e., tempered glass) and a backing substrate.

Amorphous silicone—a more recent product—is manufactured by depositing a thin film of silicone onto a substrate. One previous application is the PV strip on calculators. Since it does not have an ordered structure as crystalline silicone, amorphous silicone has lower efficiency. An advantage is that less material is needed to manufacture a PV cell and that PV cell is more flexible than crystalline silicone.

Types

Roof-mounted arrays and building-integrated photovoltaics (BIPV) are two types of PV systems. Figure 2 (on page 70) summarizes these two systems. Roof-mounted systems can vary from arrays on a roof (similar to a carpet) to arrays placed in a frame connected to the building structure (see photo 1 on page 70). The frame is placed at an angle and orientated to maximize the solar radiation on to the arrays. More sophisticated systems can track and adjust to the sun's daily movement or concentrate the sun's rays to a collection point.

Since these systems require connection to the building, the services of a structural engineer are required to determine if the existing structure can support the new PV system (due to increases in dead, wind and seismic loading). If not, structural reinforcement will be needed. Roof-mounted arrays can be installed independent of the roof and have a separate warranty. Whether installing PV systems on new or existing roof coverings, the owner should check with the roof manufacturer to ensure that the PV system will not affect or void the roof warranty.

BIPV have the PV cells bonded directly to the roofing material, either in the field or factory (see photo 2 on page 70). Amphorous silicone is typically used due to its flexibility. The membrane manufacturer usually provides a single warranty that covers both the roof system and PV cells. BIPV product types include shingles, metal roofing, concrete tiles, built-up roofs, and single-ply membranes.

New innovations include cylindrical PV units that can be set on the roof system. These systems are able to generate electricity from sunlight striking the unit and reflecting off the roof surface. A PV consultant can assist an owner with selecting the appropriate PV system for the building and site.

Incentives

Although costs have decreased, incentives are still needed to make PV systems economically competitive with conventionally-generated energy. Possible incentives are available from federal, state and local governments. Some utilities offer incentives and/or rebates since PV-generated electricity reduces the amount of utility-generated power. These incentives vary by state and region and can include tax rebates and accelerated depreciation. For example:

- 25 states offer grant programs and/or tax credits for renewable energy systems;
- 32 states and Puerto Rico offer property tax incentives for renewables;
- 23 states, the District of Columbia and Puerto Rico offer rebates for renewables;
- 27 states offer sales tax incentives for renewable energy systems;
- 31 states offer loan programs for renewable energy systems; and
- The State of California has a program to have 1 million solar roofs by 2018. The California Solar Initiative offers rebates to assist in reaching this goal.

When considering a PV system, research the available incentive programs in the project area. Two good resources include the Database of State Incentives for Renewables and Efficiency (www.dsire.org) and the U.S. Department of Energy (www.energy.gov).

Other funding options include Purchase Power Agreements and Property Assessed Clean Energy programs. A PPA is a financial agreement in which a third-party investor installs, owns, operates and maintains the PV system. The property owner agrees to have the PV system installed on the property and purchases the PV-generated power at a specific rate for a predetermined period.

The PPA may include a clause allowing the owner to buy the PV system after the PPA period has ended. Owner benefits include no up-front capital costs, predictable energy costs and possible increased property values. Challenges to the owner include complex PPA negotiations and the possibility of receiving two energy bills if the PV-generated electricity does not satisfy 100 percent of the building electrical needs.

Presently, 15 states and Puerto Rico authorize or allow third-party PPAs. A PACE program enables a property owner to borrow money from a local government entity (i.e. city or county) to install a PV system and repay the loan through a special assessment to their property tax over a 15- to 20-year period. Twenty-one states and the District of Columbia offer PACE programs.

Planning and design

When considering a roof PV system; proper planning, design, construction, and maintenance are integral to the system performing as intended. Remember that the main purpose of a roof is to keep the underlying interior space dry and thermally regulated. If PVs are installed on a roof and the roof subsequently leaks, the benefits of the PVs will be offset by the consequences of the leakage. There are many things to keep in mind when considering a PV project.

First, determine the energy requirements for the building then estimate the PV size (based on budget and available roof area) and calculate the estimated energy generation and available economic incentives.

It’s important to consider variables affecting system performance include geographical location, solar radiation and weather data, physical orientation, and shading and shadowing from nearby structures and trees.

If the system is set on a fixed mount, the panels should be permanently set to the winter angle.

Additionally, PV systems are rated by energy produced under standard test conditions. Remember to include losses due to temperature, dirt accumulation on the PVs, wiring, and the inverter when estimating energy generation. For example, dirt on the PV surface will reduce the amount of sunlight that strikes the PV—some research has found losses of up to 10 percent.

A structural engineer should also determine if the existing structure can support the new PV system and if not, design structural augmentation. For roof-mounted arrays, connection of the PV to the building structure must be analyzed and designed by a qualified professional.

Since PV efficiency decreases as array temperature increases, provide for ventilation at the array back for roof-mounted arrays.

Furthermore, the following good roofing practices should always be followed:

- The roof should slope to drain with a ¼ inch per foot minimum slope;
- Roof-mounted items—such as curbs for PV arrays—should not obstruct the flow of water. Curbs and other penetrations such as stanchions should be 8 inches high above the finished roof surface and be spaced at least 30 inches apart;
- Roof-mounted PV arrays should have supports with circular cross sections to facilitate flashing. The flashings should be durable and preferably sheet metal or lead sleeve flashings that are counter-flashed with sheet metal storm collars with sealed drawbands;
- There should be adequate clearance between the roof and underside of the PV system for ventilation and maintenance access; and
- Minimize electrical penetrations and avoid grouping conduits.

If you are planning to install a roof-mounted array on an existing roof, make sure that the remaining roof service life is compatible with the PV service life. Do not install a 20-year PV system on a roof with five years of remaining service life.

BIPVs are relatively new to the market and there are concerns about the darker PV absorbing heat, resulting in higher temperatures at the PV/roofing interface and creating possible damage to the underlying roofing. Ensure that the allowable temperature of the roof system will not be exceeded during PV design operating temperatures. If a single-ply roof is specified, a fully-adhered system with a 72-millimeter minimum thickness is recommended. There should be a thermal and puncture resistant cover board installed directly under the roof membrane.

The roof and PV system needs to comply with the building code fire rating and provide access for firefighters in accordance with local building codes. For example, the California State Fire Marshall recommends 4-foot wide clear areas at roof edges and access hatches, access paths and limited PV array size (150-foot maximum in all directions).

A monitoring system allows the owner to determine if the PV system is performing as intended. Available monitoring systems vary from instantaneous readouts on the face of the inverter to data collection devices that record and store performance and weather data over time.

Since PV cells are expensive, theft of these systems appears to be increasing. Methods to reduce the risk of theft include one-way fasteners, motion detection lighting, a transparent protective shield, etching information on to the panels and alarms.

Maintenance and operation

Periodic inspection and maintenance should be performed for optimal performance. For example, dirt and dust can accumulate on top of the PV cells (called soiling). In regions where rain is intermittent in the summer, this soiling can significantly reduce electrical generation. Thus, the PV cells need to be cleaned periodically. Additionally, two roof inspections are recommended per year—one in the fall and another in the spring. As PV cells are active when there is sunlight, ensure that there are not live contacts for the maintenance workers and the system is properly grounded.

An alternate source with benefits

The bottom line is that if properly planned, designed, built and maintained, roof-top photovoltaic systems can provide building owners with an alternate source of renewable energy, reduced costs and enhanced sustainability.