NRCA

PV-ready Roofs

The fundamental concept of photovoltaic systems involves PV cells, which are contained in a PV module or panel and convert radiant energy (sunlight) into direct current electricity. Rooftop-mounted PV systems offer some advantages over ground-mounted PV systems. First, rooftop-mounted PV systems take advantage of otherwise underutilized rooftop space instead of valuable ground-level real estate. Rooftops also are relatively secure from passersby whereas ground-mounted systems typically need to be fenced off or otherwise secured to limit access. For low-slope roofs, roof-top-mounted PV systems also may not be visible to passersby. Also, because rooftop-mounted PV systems are located on buildings, they are close to electrical transmission lines already servicing the buildings. With the goal of eliminating or at least reducing carbon emissions and energy in the building and construction industry, renewables, which include solar or PV, are going to be a significant contributor to that goal and increase in use in the coming years.

Background

A facet within the PV industry is the solar power purchase agreement. An SPPA is a financial agreement/contract where a third party, such as a PV company, designs, installs, owns and operates a PV energy system on a customer's roof at little to no cost. SPPAs are available to homeowners and commercial building owners. The PV company sells the electricity generated to the homeowner/building owner at a rate that is typically lower than the local utility's retail rate. SPPAs usually are long-term contracts that range from six to 25 years, and the PV company is responsible for the operation and maintenance of the PV system for the duration of the agreement. The benefits of SPPAs to homeowners and building owners are:

- No capital costs
- Reduced electricity costs
- Limited system performance risk
- Potential increase in property value

However, homeowners and building owners should be aware of potential costs with an SPPA. An existing roof assembly or membrane may need replacement or repair to support the installation of a PV system or comply with local codes/ordinances. This also might include trimming trees that will shade the PV system. In addition, the potential for increasing the property's value comes with possible higher property taxes.

To better understand the process of converting sunlight into electricity, it is important to understand some basic terminology applicable to PV systems.

ASTM E772, "Standard Terminology of Solar Energy Conversion," defines the term "photovoltaic cell" as "the basic semiconductor device that generates electricity by the photovoltaic effect when exposed to radiant energy such as sunlight."

In the manufacturing process, PV cells are packaged or grouped into PV modules. ASTM E772 defines the term "photovoltaic module" as a single package containing two or more electronically interconnected photovoltaic cells, including a frame or integral mounting points, and means for electrical connection; this may be suitable for field installation without additional modification.

During the manufacturing process, PV modules are grouped into PV panels, which are discrete units designed to provide field-installable units. ASTM E772 defines the term "photovoltaic panel" as a number of modules that are electrically connected, mechanically integrated and designed to provide a field-installable unit. PV panels are grouped together into PV arrays. ASTM E772 defines the term "photovoltaic array" as an assembly of photovoltaic panels or modules with support structure and other components (if used), to form a complete DC power-producing circuit.

Because the electrical output of PV modules and panels is DC electricity, it requires conversion to alternating current for home and building usage. The conversion of electrical current from DC to AC takes place in an inverter. NFPA 70: National Electrical Code defines the term "inverter" as "equipment that is used to change voltage level or waveform, or both, of electrical energy. Commonly, an inverter [also known as a power conditioning unit (PCU) of power conversion system (PCS)] is a device that changes dc input to an ac output. ..."

Code compliance for rooftop building-integrated photovoltaic systems, including PV shingles, is complex. Building-integrated photovoltaic panel (BIPV) systems have dual functionality as roof coverings and electricity-generating products. This dual functionality can lead to confusion and disputes about who should install and maintain such systems. In addition, various code requirements further complicate the issue. There are several crucial factors that building owners, designers, installers and utility companies should take into account to ensure rooftop-mounted PV systems are properly installed. Additional discussion may be found in the *Professional Roofing* article "A turf war," October 2023 issue.

Rooftop-mounted PV system installation always should involve a professional roofing contractor and may also need to involve a licensed electrician. An electrician may be necessary to oversee the proper installation of a PV system's electrical components; most jurisdictions have requirements for licensed electricians to perform that function. Also, several states and local governments have enacted special licensing requirements for PV system installers.

Rooftop-mounted PV system installations only should be undertaken with the involvement of a professional roofing contractor employing skilled roofing workers for several reasons, including:

- A roofing contractor will assess the roof's condition. Installing expensive PV systems on an aged or faulty roof system will lead to unintended results.
- A roofing contractor knows how to install new roof systems properly and safely to best accommodate rooftop-mounted PV systems.
- A roofing contractor will be aware if a particular roof system manufacturer requires "PV-ready" installations for warranties.
- A roofing contractor should be aware of local building code requirements and the need for proper coordination that pertains to the installation of the rooftop-mounted PV systems. These requirements typically include provisions for wind resistance, fire resistance, structural loads and access requirements; simply installing a rooftop-mounted PV system over an existing roof system component can lead to building code violations if not done properly.
- A roofing contractor knows how to organize a roofing job site, properly load materials on a roof, and keep building occupants and passersby free from risk.
- A roofing contractor is trained—and insured—for rooftop safety. Falls remain one of the primary sources of injury in the roofing industry. Workers who are not aware of best safety practices or Occupational Safety and Health Administration requirements not only put themselves in danger but also may be putting the building owner at risk. In addition, roofing workers are insured for workers' compensation at a rate appropriate for work on rooftops. That is not likely to be the case for other tradespeople, and disputes can easily arise in the event of a claim for improperly insured contractors.
- Often, rooftop PV system installations require penetrations through the roof system. A roofing contractor understands how to properly secure equipment on rooftops, knows how to apply flashing materials and understands how attaching equipment to a roof system may affect its long-term watertightness.
- Transporting material and equipment across a rooftop can damage the roof system. A roofing contractor understands proper methods to move material and equipment across rooftops without causing damage.
- Many roof systems carry warranties issued by roofing contractors and roofing material manufacturers. All these warranties include provisions that void them if alterations are made to the system (including any attachments) without the manufacturer's prior approval.

Roofing contractors may not be permitted to install PV-related equipment depending on the requirements of local jurisdictions. Even in areas where roofing contractors do not install PV systems, such equipment sometimes may be encountered during roof system repair or maintenance so roofing contractors can benefit from following safety-related guidance. The risk of shock is always present in live electrical circuits such as those associated with rooftop PV systems.

Considerations

An important design consideration when considering a rooftop-mounted PV system is for the roof system to have an expected service life equal to or greater than the PV system. This helps minimize the need to dismantle or remove the PV system to provide for necessary repairs or complete removal of the roof system to maintain building watertightness. PV systems often are reported to be manufactured to have service lives of about 25 years with some claiming up to 40 years. Specific service life information is available from individual PV system manufacturers.

Roof systems, on the other hand, have service lives that vary significantly depending on the specific roof system design, roofing materials used, installation workmanship and owners' maintenance. Although some roof system types—such as slate, clay tile and copper architectural metal panel—have been known to have service lives of 50 years or more, other roof system types have significantly shorter service lives. An industrywide roofing study conducted in 2003 by The Roofing Industry Alliance for Progress shows the average life expectancy of a low-slope roof system on a commercial building is 17.4 years. Based on this, NRCA has concluded above-average roof systems should be installed on buildings where rooftop-mounted PV systems are being installed or where rooftop-mounted PV system installation is anticipated.

Another thing to consider is PV system manufacturers typically require PV system installers be licensed or certified by the PV system manufacturer. It is common for manufacturers of rooftop- mounted PV systems to designate approved roof substrate types for the attachment of their products.

To verify whether a roof system in a proposed design is a PV manufacturer-approved substrate, the PV system designer should consult the PV system manufacturer.

In addition, PV modules are susceptible to damage resulting from impacts from hail. ASTM E1038, "Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls," and FM 4478, "American National Standard for Roof Mounted Rigid Photovoltaic Module Systems," address the ability of PV modules to withstand the impact forces of hailstones. PV system designers may have difficulty finding PV module manufacturer data related to ASTM E1038 and FM 4478 for specific products because compliance with these documents is not required in relevant codes and standards. PV system designers are encouraged to use ASTM E1038 and FM 4478 data related to hail-impact resistance when designing PV systems, especially when such systems are installed in areas where hail is common.

Note that accumulated dirt, debris and atmospheric fallout on PV systems can reduce their efficiencies. But certain cleaning solutions, such as those with strong alkali content, used to clean PV may be detrimental to roof coverings. Cleaning materials with relatively neutral pH (mild soap and water solutions) typically are safe to use. Verify with PV and roof system manufacturers that the cleaning solution will not prematurely deteriorate or stain a roof system. PV component manufacturers' product manuals indicate moderate-intensity rain is adequate to effectively clean sloped modules.

According to PV manufacturers, snow cover typically will slide off angled PV modules shortly after being exposed to sunlight. There should be room below modules or panels to allow snow to slide clear of them. When necessary, manufacturers should be consulted for approved cleaning and snow removal procedures if heavy snow accumulations cause PV module surfaces to be insulated from radiant solar energy.

Roof system manufacturers typically require work be performed in accordance with their specific recommendations to maintain warranties. This may include, but is not limited to, flashings and counterflashings, roof system penetrations, bearing conditions on the roof system and roof system terminations. Any work to the roof system may require preauthorization from the manufacturer to maintain the roof system warranty. Building owners and PV contractors should consult the roof system manufacturer or roof contractor providing a warranty before installing a PV system.

Codes and standards

Both the International Building Code® and International Residential Code® contain specific requirements for BIPV roof panels and shingles too extensive to address here; following are some highlights.

In the 2024 IBC's Section 1505.9—Rooftop mounted photovoltaic (PV) panel systems, it states: "Rooftop mounted photovoltaic (PV) panel systems shall be tested, listed and identified with a fire classification in accordance with UL 2703."

It also states the fire classification of a system must be based on the type of construction of the building. IBC's Section 1604.5.2—Photovoltaic (PV) panel systems states: "4. Rooftop-mounted PV panel systems and elevated PV support structures installed on top of buildings shall be assigned to the same risk category as the risk category of the building on which they are mounted." This means the same PV system may not be installed on a warehouse and a hospital without modifications to meet a higher risk category.

IBC Section 1507.16.6—Material standards (BIPV shingles) and Section 1507.17.5—Material standards (BIPV roof panels) require listing and labeling in accordance with UL 7103, "Outline of Investigation for Building-Integrated Photovoltaic Roof Coverings."

IBC Section 1607.14.3—Photovoltaic panel systems contains the minimum dead and live loads a roof structure and elevated PV support structure(s) must resist, including ballasted PV panel systems.

The 2024 IRC's Section R329–Solar energy systems addresses rooftop-mounted PV and BIPV systems. IRC Section R329.3.1—Equipment listing states PV panels and modules must be listed and labeled in accordance with UL 1703, "Standard for Flat-Plate Photovoltaic Modules and Panels," or both UL 61730-1, "Standard for Photovoltaic (PV) Module Safety Qualification" and UL 61730-2, "Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements for Testing." IRC Section R329.4.1—Structural requirements provides for the minimum roof loads and wind loads for rooftop-mounted PV systems. IRC Section R329.4.2—Fire classification states PV panel systems must have the same fire classification as the roof assembly.

For elevated PV support structures, IRC Section R329.7—Elevated photovoltaic (PV) support structures states a support structure is considered a roof for the purposes of establishing the number of stories and fire separation distances. IRC Section R329.7.1—PV panels installed over open-grid framing or noncombustible deck states that PV panels must be tested, listed and labeled with the UL standards with UL 1703 or both UL 61703-1 and UL 61730-2. However, PV panels marked as "not fire rated" are not permitted to be installed on elevated PV support structures.

Roofs are differentiated into two general types primarily based on the incline of the finished roof's surface. The I-Codes define these as:

- Low-slope: A roof slope less than 2 units vertical in 12 units horizontal (17% slope)
- Steep-slope: A roof slope 2 units vertical in 12 units horizontal (17% slope) or greater

The *2024 International Energy Conservation Code's*® Appendix CB, Solar-ready Zone—Commercial and Appendix RB, Solar-ready Provisions–Detached One- and Two-Family Dwellings and Townhouses contain general requirements for roof areas. Both appendices apply only to new construction. The commercial appendix applies to buildings five stories or less in height and oriented between 110 and 270 degrees of true north or have low-slope roofs. The residential appendix states a minimum of 150 or 300 square feet of PV-ready roof area is required depending on the type and size of structure. There may be local jurisdictions, such as California, that essentially require all available roof areas, with exceptions, on single-family residential structures to be PV-capable.

Steep-slope roofs

There are two main types of residential PV systems. Traditional PV panel systems (rack and panel) and integrated PV roof systems. A relatively new option for PV systems for steep-slope roof systems are BIPV products. These systems are designed to be installed in areas of the roof in lieu of traditional roof coverings and serve as a PV and roof covering system. Requirements for such systems are included in the 2024 I-Codes and should be installed following manufacturer's instructions. Another type of BIPV product is PV shingles, which mimic the look of traditional asphalt shingles and have PV components built in. This type of BIPV offers the lowest profile.

Traditional PV panels typically require a secondary installation performed by a solar company. Rack-mounted PV systems generally need to be mounted to roof structural members, such as rafters or trusses. Provisions to raise rack-mounted PV systems above the roof surface to ensure unobstructed drainage and ventilation space under PV modules must be provided. Self-adhering underlayment may be required below a PV panel system installation.

Installing traditional PV panels on an existing roof could compromise or void the shingle manufacturer's and/or installation warranty. Damage by a PV contractor to an underlying roof surface would not constitute a material manufacturing defect and, therefore, would not be covered by the shingle manufacturer's warranty. Similarly, installation workmanship of the PV mounting system or damage to the roof system from the mounting system installation would not be a covered roof workmanship warranty. In addition, it is likely a manufacturer's material warranty claim would not cover the removal and reinstallation of a PV panel system. It should also be noted damage can more easily occur on steeper roof slopes or with installations during hot weather.

The proper installation of rack-mounted and direct-to-deck PV panels by a solar contractor on an existing roof is required to prevent costly leaks and other issues. A solar contractor must protect an existing roof's surface when installing a traditional PV panel system. If a PV system installed on an existing shingle roof surface requires the installation of mounting systems that will cut shingles or break the seal between shingles, a roofing contractor should be involved and properly reseal the shingles in accordance with the shingle manufacturer's instructions. Solar contractors must follow shingle manufacturer installation instructions in addition to the PV panel and mounting manufacturer installation instructions.

PV shingles are installed much like a typical asphalt shingle by a qualified roofing contractor. This incurs less cost than two contractors as with a traditional PV panel system. PV shingles can be installed in about the same amount of time as a typical asphalt shingle roof covering. As previously noted, PV shingles should be UL-rated and comply with applicable local building codes. PV shingles and typical architectural shingles age at the same rate.

Whether a steep-slope roof is right for a PV system depends on existing roof condition, location of roof, age of roof, trees in the vicinity of the roof, direction of roof surfaces, and model and size of panels. Soiling of PV panels and PV shingles occurs naturally. Homeowners should regularly clean their PV panel/shingles as recommended by the manufacturer. Caution should be exercised as cold water on a hot PV panel/shingle could crack or damage the unit. In addition, homeowners should have their PV systems occasionally inspected. Average residential PV systems have a payback of five to 10 years, and online tools are available to determine payback for PV system installations. There may be government incentives, tax credits and rebates to offset initial costs of a residential PV system.

Low-slope roofs

In 2013, SPRI issued Technical Bulletin 1-13, "Summary of SPRI Membrane Manufacturer Photovoltaic (PV) Ready Roof Systems." It provides general guidelines for making a roof system PV-ready and anticipating potential risks associated with installing a PV system on an existing roof system.

Information for the bulletin was collected from a survey of SPRI manufacturer members' websites and literature. In the bulletin, SPRI indicates some manufacturers may have their own PV-ready programs, which may not contain all the elements in SPRI 1-13. SPRI 1-13 and membrane manufacturers address issues such as dead and live loads; fire resistance; service life concerns; appropriate PV-ready roof membranes; requirements for existing roof systems to maintain warranties; roof drainage, anchorage or attachment methods; pre- and post-installation inspections; project documentation requirements; heat effect on roof membrane; and additional services a roof membrane manufacturer may offer, such as roof membranes and acceptable roof membrane types. Manufacturers also may require the use of an adhered, high-compressive-strength insulation board with an adhered roof membrane. on roof membrane; and additional services a roof membrane manufacturer may offer, such as roof membranes and acceptable roof membrane types. Manufacturers also may require the use of an adhered, high-compressive-strength insulation board with an adhered roof membrane.

PV system installations over low-slope roof systems are recommended only if the roof system has been designed for PV system installation. Designers of low-slope roof systems for PV applications should specify the following enhancements:

- Any above-deck insulation should be high-compressive-strength, rigid board insulation.
- For membrane roof systems, a thermal barrier cover board should be located directly underneath the roof membrane.
- For single-ply membrane roof systems, membrane thickness should be increased per manufacturer recommendations.
- Reflective roof surfaces or coatings that provide enhanced protection against the effects of ultraviolet radiation and high service temperatures should be used.
- Curbs should not impede the flow of runoff water from draining off the roof surface.
- A curb never should be set on or fastened through roof insulation. All curbs should be firmly anchored to a properly supported roof deck.
- The top of the curb should be level after installation.
- The curb and PV rack should be structurally capable of supporting design loads and located so no penetrations, drains, cables, conduit, etc., will pass through or obstruct the flashings.
- The curb should be furnished with a wood nailer mounted at the top of the curb but below the curb cap to permit mechanical attachment of the flashing material.
- There should be compatibility/equivalency between UL and FM fire and wind evaluations.
- There should be walkway pads for PV system access and service.
- Space for fire lanes between PV arrays should be available in accordance with the local jurisdiction's fire code.

Other factors to consider when adding PV panels to an existing low-slope roof should include:

- Installing a PV system on a roof membrane that will require replacement before the end of life of the PV system will incur additional cost for the removal and replacement of the PV system to replace the roof system.
- Is the existing roof structural system capable of resisting the PV system dead and live loads?

An additional resource for PV roof systems is FM Global Data Sheet 1-15 Roof-Mounted Solar Photo- voltaic Panels. The document provides information about fire and related natural hazards, design, installation, operation and maintenance of rooftop PV panels that generate electricity. Natural hazards addressed in the data sheet include windstorms, hail, snow, ponding and earthquakes. Exposure to fire hazards caused by combustible materials below PV systems also is addressed. The data sheet states a Class A roof assembly no longer qualifies for that rating once a PV system is installed above it. Recommendations for wind design including design wind speeds, exposure category, topographic factor and importance factor along with additional criteria are provided. The installation of PV panels over various roof systems also is provided.

Installing PV systems on new or existing roof surfaces requires careful assessment and execution and should include a professional roofing contractor. To assist with an assessment, NRCA has published *Guidelines for Rooftop-Mounted Photovoltaic Systems, 2nd Edition*. These guidelines are intended to provide industry best practices and technical information concerning the design, materials and installation of rooftop-mounted PV systems. The guide reflects the consensus of the roofing contractors consulted; the guide does not purport to include all practices, designs or applications. The guide is an authoritative technical reference concerning the design, materials and installation of quality, long-lasting rooftop-mounted PV systems.