CENTER FOR ENVIRONMENTAL INNOVATION IN ROOFING

SUCCESSFUL ROOFTOP PHOTOVOLTAICS:

How to Achieve a High-Quality, Well-Maintained, Compatible Rooftop PV System

The Benefits of Rooftop PV

The rooftops of North America offer an attractive platform to achieve long-term energy-independence while reducing environmental impact and sustaining a strong economy and society for future generations. This rooftop "platform for the future" is especially attractive for the deployment of photovoltaic (PV) systems which generate electricity through the direct conversion of sunlight into usable electrical power. According to US Census data[1], the rooftops of the United States alone offer over 200 billion square feet of potential surface area for the installation of PV systems. Assuming only 25% of this area is suitable for unobstructed and continuous PV operation, the total energy-generating potential exceeds 50,000 megawatts, or the equivalent of over 10 Grand Coulee Dams[2].

The benefits offered by rooftops for the economical and sustainable deployment of renewable solar energy also include:

Access to Sunlight. Because the roof surface is generally located above the "shade line" for trees and adjacent structures, this surface offers virtually unobstructed access to available solar energy.

Low-Cost Solar Real Estate. Because rooftops are already serving a functional purpose by keeping water out of buildings and helping generate economic value in the form of occupancy or rent, their use as a platform to generate solar energy is generally much less expensive than the acquisition of undeveloped real estate. In addition, development costs, including design, zoning, infrastructure, etc. may be significantly lower using existing rooftops as compared to developing a new, free-standing solar generating facility.

Unobtrusive, Secure Location. Because roof surfaces are generally located above the "streetscape" the installation of rooftop solar may not overly impinge on the daily activities and ambience of developed communities. In addition, because roofs offer limited accessibility, rooftop solar systems are inherently easier to secure as compared to ground level installations.

Close to the Customer / Close to the Grid. In general, the users of the energy generated by rooftop solar are located directly beneath the rooftop, reducing transmission and operating costs. In addition, because rooftop solar is generally located directly within the current developed electric grid, no new transmission lines or controls are necessary.

Attractive Investment. The economics of rooftop solar are becoming increasingly attractive for both commercial and residential customers. For the homeowner, the cost of rooftop solar after available federal and local incentives may generate up to a 15% return on investment[1] in some states and for commercial owners, the use of "power purchase agreements" combined with growing federal and local incentives provides an attractive ROI in many areas of North America.

Material Synergies. Using modern materials technologies, the energy generating and waterproofing functions of rooftop solar can be effectively combined into Building Integrated Photovoltaic (BIPV) systems, offering significant material, installation, and maintenance cost savings.

816 Connecticut Ave, NW
Fifth Floor
Washington, DC 20006
Toll Free 866.928.CEIR
Phone 202.380.3371
Fax 202.380.3378
www.RoofingCenter.org

The Challenges of Rooftop PV

In addition to potential benefits, the growing deployment of rooftop solar across North America also poses a number of challenges that must be effectively addressed in order for rooftop solar to achieve its promise. These critical challenges include:

Maintaining Roof Watertightness. The primary function of a roofing system is to maintain watertightness and resist the penetration of moisture into the underlying building. However, the installation of a PV system may create conditions that may jeopardize the ability of the roofing system to successfully perform its watertight function. Many PV systems create new roof penetrations and attachments that may cause leakage and interfere with drainage. In addition, the PV system may add new loads to the roof, such as increased weight, added heat and reflected ultra-violet rays that may damage the roof unless countermeasures are implemented. PV installation will also add service loads that can damage the roof during normal use and routine system maintenance of both the roof and the PV system; and these additional service loads also will require the implementation of design and operating countermeasures to assure long-term watertightness.

The Bottom Line: With the installation of a rooftop PV system, the roofing system becomes more than just a roof – it becomes a permanent platform for the continuous operation, service and maintenance of the PV system.

Maintaining the Roof Warranty. Billions of square feet[4] of commercial roofing installations across North America are protected by manufacturers' limited warranties providing for the repair of the roof in the event of leaks. In addition, many commercial building owners rely on this limited warranty protection as part of their overall roof system maintenance program. Like all limited warranties, however, the coverage offered may be severely limited if critical design, installation and/or maintenance procedures are not followed. From the start, the roofing system must be designed and installed in accordance with roofing manufacturer specifications, and PV system details must be accepted by the warranty roofing system manufacturer prior to installation. In addition, the building owner or owner's agent must follow specific maintenance and notification requirements in order to maintain the full force and effect of the limited warranty.

The Bottom Line: Roofing warranties are a valuable tool for the building owner, but they carry important limitations and conditions that must be addressed for successful rooftop PV installation and operation.

Maintaining Continuous Operations. Because many commercial roofing installations are financed using long-term Power Purchase Agreements (PPAs), the continuous, undisrupted generation of solar power is critical to the fulfillment of the terms of the PPA. As a consequence, the margin of safety required in the design, installation and maintenance of the roof may likely exceed normal expectations and minimum standards for commercial roofing systems. As an example, commercial roofing systems are generally designed to resist "typical" weather events such as rain, snow, and wind; but they are not always designed to meet unusual weather events such wind-blown debris, hurricanes, and hail storms. In addition to the damaging potential of unusual weather events, it is important to recognize that repairs for such damage may add to the disruption by requiring the temporary removal and reassembly of the rooftop PV system in order to repair the underlying roofing system.

The Bottom Line: A rooftop PV system should be designed not to simply "make it through the storm," but to minimize the need for major repairs or replacement that could compromise the continuous operation of the PV system.

Meeting Building Codes. Given its installation on and integration with the roofing system, rooftop PV systems must meet a number of important criteria prescribed by modern building codes. First, the combined roofing / PV system must meet or exceed external fire standards as required by the governing building code. Conventional PV arrays usually do not affect the fire rating of the underlying roofing system, but thin-film laminates generally must be tested and certified to meet fire code requirements. In addition, the combined PV / roofing system must meet or exceed wind uplift resistance standards as required by the governing building code. Both conventional PV arrays and thin-film laminates generally must be tested and certified to meet wind uplift code requirements.

> ***The Bottom Line: A rooftop PV system must be designed and installed to meet critical building code requirements, including but not limited to external fire and wind uplift standards – and fulfillment of these standards generally requires testing and certification of the combined PV / roofing system.***

Managing Safety Risks. The combination of roofing and energy generation combine several risks that make rooftop PV systems unique as compared to either normal roofing or electrical activities. Because of the high voltage generated by PV, ground protection and access to switchgear and conduits pose important safety risks. And because rooftop PV is installed at a considerable height above the ground, fall protection becomes a critical safety issue. Because of these critical safety risks, insurance requirements are also important, especially general liability and workmen's compensation coverage. Finally, it is important to note that these risks do not end with the successful installation of a rooftop PV system – they continue every day the system is in operation on the rooftop, and hence, high voltage and fall protection becomes a daily requirement.

> ***The Bottom Line: A rooftop PV system presents a combination of risks that must be addressed, including high voltage operation, fall protection, and insurance coverage – and these risks are present every day the rooftop PV system is in operation.***

Managing the Investment Horizon. Although rooftop PV systems are becoming more and more attractive as investments, the investment horizon remains very long – generally at least twenty years to achieve an acceptable return on investment. As a consequence, the underlying roofing system must also provide this same minimum investment horizon in order to realize the full potential of rooftop PV. As illustrated by many of the previous challenges identified in this paper, one of the most critical determinants of the longevity of the roofing system is the **compatibility** of the system when used in conjunction with a PV system. In addition, the longevity of modern roofing systems may vary significantly depending on the **quality** of materials, design details and installation practices used to integrate these materials. Finally, all modern roofing systems, regardless of the amount of robustness built into the system, must be **well-maintained** over time to assure optimal service life is achieved.

Assuring the effective match between a roofing system and a PV system is especially critical whenever the installation of a PV system is contemplated over an **existing roof.** Not only must the remaining service life of the existing roof system is adequate to meet or exceed the investment horizon of the PV system, but a detailed review of the compatibility of the existing roof to accommodate the PV system – both initially as well as during ongoing operations – will be critical to assuring that long-term investment objectives will be achieved. In some cases, the existing roof can be retrofitted or upgraded to provide the necessary service life and compatibility with the PV system; but many situations may arise where to existing roofing system is simply inadequate to match the required investment horizon.

> ***The Bottom Line: Failure to match the investment horizon of the roofing system and the PV system will likely have an adverse effect on long-term rooftop PV investment return.***

Meeting the Challenges of Rooftop PV

Because the potential benefits of rooftop PV offer so much in terms of long-term energy independence and environmental sustainability, and because the unique challenges of matching PV systems to compatible roofing systems are so critical, the Center for Environmental Innovation has developed a set of guiding principles that can be used by designers, building owners, and the PV investment community to assure that the combined rooftop PV system is designed, installed and maintained for optimal economic and environmental benefit.

Successful Rooftop PV: Guiding Principles

1. **Start with a high quality, well-maintained roofing system designed for compatibility with the intended PV system, or upgrade an existing high quality roofing system for compatibility with the PV system.**

   Make sure the roofing system will provide at least 20 additional years of useful service. Use a cover board as a substrate for the roofing membrane to prevent damage and protect the energy efficiency of the roof insulation. Match roof membrane thickness and proven performance to the required service life of the PV system. Elevate framing and conduits above the roof surface to promote drainage.

   Also make sure the roofing system is well-maintained so that continuous operations are not affected. Stop potential leaks before they start. Use round framing at penetrations. Install sacrificial membrane layers or walkways at critical traffic locations. Provide additional membrane layers or coatings at flashings. Establish a formal periodic inspection program to verify the condition of the roofing membrane, flashings, and all critical roof system details

2. **Make sure the roofing warranty is not compromised by the PV system installation.**

   Make sure the roof system manufacturer has accepted all PV system details - especially attachments & penetrations – prior to PV system installation. Initiate a long-term roof maintenance program with qualified roofing professionals. Maintain communications with the roof system manufacturer and roofing contractor.

3. **Make sure the PV roofing will do more than just "make it through the storm" to help insure continuous operations.**

   In areas of high rainfall or snow, increase flashing heights and roof drainage provisions. In hail zones, select only tested hail-resistant PV / roofing assemblies, and increase roof membrane thickness and install cover boards to minimize hail damage. In high wind zones, select only tested high wind-uplift PV / roofing assemblies, and add sacrificial membrane layers and install cover boards to minimize damage from wind-blown debris.

4. **Anticipate and plan for the high levels of service traffic and other impacts associated with PV.**

   To accommodate the effects of high maintenance traffic, Install protective walkways, increase membrane thickness, and add protective cover boards. In addition, establish operational controls, such as restricting roof access and maintaining a roof access log.

   To accommodate the effects of heat build-up and reflected ultraviolet frequently associate with PV systems, install a sacrificial membrane layer directly beneath the PV system to reduce heat-build-up on the primary waterproofing membrane. In addition, install additional membrane or coating layers at exposed vertical flashings to reduce UV exposure.

5. **Anticipate and plan for the eventual replacement of both the PV system and the roofing system.**

   Establish a proactive and organized approach to roof system repair & replacement. Repair or replace flashings and other critical roof details as part of an ongoing preventative maintenance program. In addition, design for roof replacement that does not interrupt operation. For example, consider "re-skinning" the existing roof membrane in lieu of complete removal and replacement.

6. **Engage qualified professionals to insure all building codes and safety regulations are met.**

   Involve qualified roofing professionals as important members of the initial design and planning team. Obtain assurances that local building codes are being met, and require all installation and service personnel to meet rooftop safety regulations
   Finally, keep roofing professionals involved in the ongoing service of the roofing system.

These guiding principles are intended to offer a starting point for the effective selection of high-quality, compatible and well-maintained rooftop PV systems, but they must be supplemented by additional information available from other roofing industry sources, including non-profit associations, testing and standards organizations, code bodies, and professional roofing consultants, contractors and manufacturers. For more information about the effective implementation of these guidelines, please contact the Center for Environmental Innovation in Roofing, visit the Center's website, or contact any member of the Center.

Notes:
1. Derived from US Census Bureau data by TEGNOS Research, Inc. (2008).
2. Assumes 1watt average solar power production during daylight hours per square foot of suitable roof surface (200 billion square feet total roof surface X 25% suitable usage factor X 1 watt / square foot = 50,000 megawatts).
3. "Will Demand for Solar Home Pick Up?" *Business Week*, 11/03/08.
4. Hoff, J. L. (1997). "Historical Warranty Cost: An Effective Measure of Long-Term Roof System Performance." *Proceedings of the Fourth International Roofing Symposium*, Gaithersburg, MD.