

Solar Design Guidelines

Commercial

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Solar Design Guidelines (Commercial)

These guidelines provide reference to the U.S. roofing industry's best practices and industry experts' recommendations for incorporating photovoltaic (PV) systems into a roof. A majority of the guidelines are adapted from 'Guidelines for Roof Mounted Photovoltaic System Installations' published by the NRCA. Topics covered in the design guidelines are:

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| I. PV Technology Evaluation | VIII. PV Service Access |
| II. Roof Substrate Evaluation | IX. Racking Systems |
| III. Fire Resistance of the Roof, Racking, and PV Assembly | X. Guarantees |
| IV. Structural Loading of PV on the Roof | XI. Flashings |
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I. PV Technology Evaluation

There are many PV technologies in the market. It is critical that the installer match the right PV technology with the right roof system. Refer to GAF Solar Roofing System Specification Sheet for preferred GAF roofing systems for the different types of PV systems available.

II. Roof Substrate Evaluation

- 1) Before installing a PV system over an existing roof, consider whether the remaining roof system service life is equivalent to the expected life of the PV system (typically >20 years). If it is expected that the PV installation will function longer than the existing roof system, re-covering or roof replacement should be considered. Other factors to be considered include additional roof system penetrations, increased rooftop traffic, increased surface temperatures, etc. Match roof membrane thickness and field performance to the required service life of the PV system.
- 2) NRCA general requirements for all new roofs that will be receiving PV are as follows:
 - a. High compressive strength rigid board insulation.
 - b. Thermal barrier board located directly under roof membrane.
 - c. Membrane of increased thickness for single-ply roofing.
 - d. Reflective roof surfaces & coatings to protect against UV.

In addition to these general requirements, GAF recommends the following best practices to extend the life of the roof:

- a. Fully adhered systems for PV installations.
 - b. Use of slip sheets (sacrificial sheets) in between the contact areas of the ballasted PV and the roof. The slip sheet must be adhered (heat welded or cold applied with adhesive) to the roof membrane.
 - c. For ballasted PV systems, slope of the roof should not exceed 2" in 12".
- 3) Mechanically attached roofing systems and ballasted roofing systems have the possibility of billowing due to high wind or building pressure differences. Billowing could cause the ballasted PV system to shift, and can also lead to localized abrasion of a roof membrane, as it rubs the edges and corners of a PV mounting system (at ballast trays, for example). These types of roofing systems must be evaluated by GAF Guarantee Services on a special case-by-case basis.

III. Fire Resistance of the Roof, Racking, and PV Assembly

- 1) Evaluate all PV panels for fire performance according to fire classification tests in the latest version of UL 1703.
- 2) Consult the International Fire Code (IFC) 2012 605.11.3 for firefighting access recommendations for roof access hatches, access pathways, and equipment clearances.
- 3) It is best practice for solar contractors to contact their local fire department to determine if alternate means or methods would allow for a safer designed solar array that is acceptable to the fire department.

IV. Structural Loading of PV on the Roof

- 1) The roofing system and building structural framing should be evaluated to verify there is enough load capacity to support the weight of the PV system (modules, conduits, and electrical equipment), wind uplifts, and snow loadings. A licensed structural engineer should provide stamped drawings and calculations.
- 2) All vertical and horizontal loads should be transferred to the building structure without deforming or overloading the roofing system.
- 3) The roof deck should also be evaluated for loads due to traffic during installation and PV/Paver stacking.
- 4) Obtain UL or FM wind ratings for the combined racking/roofing systems.

V. Drainage

Installation of a PV system should not interfere with the drainage of a roof system. Consider the following when keeping drainage in mind for solar:

- 1) Elevate framing and conduits above the roof surface to allow drainage.
- 2) Install crickets if solar curbs are perpendicular to drainage flow and greater than 24" wide.
- 3) Projections through a roof system should not be located within 2 feet of valleys or designated drainage areas adjacent to drains, scuppers, or gutters.
- 4) Consider modifying solar racking heights to counter the varying thickness of tapered insulation.

VI. Thermal Movement

The PV array, electrical conduits, and roofing materials are subject to thermal movement. The effect of thermal movement may be reduced by the following.

- 1) Split larger arrays into smaller sub-arrays.
- 2) Use racking clips and attachments that accommodate thermal expansion without transferring movement to the underlying roofing systems. Some racking manufacturers have provisions for thermal expansion built into the system.
- 3) Use flexible flashing details for mechanically attached racking systems.
- 4) Incorporate thermal expansion fittings in straight electrical conduit runs.
- 5) Racking systems should not cross over expansion joints. Use Flex Conduit over expansion joints.

VII. Slip Sheets (or sacrificial sheets)

- 1) Use matching sacrificial sheet (min 60 mil TPO for TPO roofing systems) in-between contact surfaces at the roof and the base mounts of racking systems. The slip sheet should be adhered/welded to the roofing membrane, not the base mount. The slip sheet helps reduce wear & tear from movement of the array, as well as helps reduce heat build-up on the primary waterproofing membrane.
- 2) The slip sheets should be a minimum 2" wider than the contact surface area of the rack base mount on all sides.

VIII. PV Service Access

- 1) Roof mounted PV systems generally should be mounted away from mechanical units, catwalks, permanent anchors, and other rooftop structures where access is provided for service or maintenance of other rooftop equipment.
- 2) NRCA recommends designated roof hatches be used to provide rooftop entry for PV system service personnel.
- 3) Space for service traffic paths should be designated and the roof system surface in these areas protected by walkways pads or pavers.
- 4) Consult the (IFC) 2012 605.11.3 firefighting access recommendations for roof access hatches, access pathways, and equipment clearances.

IX. Racking Systems

The solar racking system should be designed so that external forces acting on the rack do not compromise roof waterproofing integrity. Loads to be considered include horizontal wind load, vertical wind uplift load, vertical dead load, and vertical snow load, as well as non-specific vibratory loads from external forces or building equipment.

GAF recommends the use of racking systems with the following:

- 1) Thermal and dynamic movement provisions within the racking system.
- 2) Minimal UV exposure of washers/gaskets.
- 3) Base mounts of ballasted PV systems with sufficient area to distribute vertical loads without cutting or compressing the underlying roofing system.
- 4) Ballast pavers that have been tested for long-term durability (for ballasted PV systems).

- 5) Racking trays/holders that can contain the deteriorated and cracked pavers from freeze thaw (for ballasted PV systems).
- 6) Compatible corrosion-resistant rack components.
- 7) Sufficient racking clearances for inspection, maintenance, repair, or reroofing.

Racking Systems should allow ease of removal by trained personnel without significantly exposing the roof system to the possibility of damage. Racking systems should also be easy to flash.

X. Guarantees

Roofing guarantees 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.

- 1) From the start, the roofing system must be designed and installed in accordance with GAF published specifications, and PV system details must be accepted by GAF prior to installation.
- 2) GAF does not guarantee the solar mount system utilized in the solar installation or any other non-GAF products on the roof. GAF therefore specifically disclaims any liability arising out of or in connection with the integrity, installation or performance of, or damages sustained by or caused by the roof mount systems.
- 3) A pre-solar inspection and post-solar inspection are required for all new & existing roofs.

XI. Flashings

- 1) PV systems using support stands should use round steel pipes or square tubes to facilitate effective flashing installation methods.
- 2) All penetrations are to be flashed in accordance with appropriate NRCA construction details.
- 3) Installation of thicker flashing membranes, additional layers of flashing membranes, or UV protective coatings is recommended for highly reflective PV system arrays.
- 4) Use flashing details that have been reviewed and approved by GAF.
- 5) Use flexible flashing for mechanically attached racking.

XII. Electrical Connections

- 1) The number of electrical roof penetrations should be kept to a minimum. Electrical cables routed through the roof assembly should not be subjected to roof abrasion. Cables passing through the

roof assembly should not travel horizontally within a roof system, such as directly under the roof membrane or in a notched-out insulation.

- 2) Penetrations of electrical conduit into the building should be properly flashed to the roof system. The NRCA recommends electrical conduit passing through a roof assembly, run inside a sheet-metal enclosure with roof curbs [e.g., doghouse]. A gooseneck-type penetration detail can be used where a cable needs to pass through a roof assembly and be flashed.
- 3) Penetration pockets (pitch pockets or pitch pans) are acceptable as a last alternative for flashing PV system electrical connections passing through a roof assembly. TOPCOAT® FlexSeal Caulk Grade Sealant is the recommended top fill material for pitch pockets.

XIII. Seismic Considerations

PV modules installed within earthquake zones shall be designed to withstand the seismic loading experienced in these areas. The design shall be verified by a professional engineer competent in this area of practice. Refer to FM Global’s Class # 4478 (Approval Standard for Rigid PV Modules) for design considerations.

XIV. Codes, Standards & Guidelines

Below is a list of reference to codes, standards, and guidelines relevant to installation of a solar PV system on a roof. These are to be used as a reference only, as the local Authority Having Jurisdiction (AHJ) will have their own requirements for compliance of the solar PV system.

Part	Agency	Code	Description
Module	UL	1703	Flat plate PV Modules & Panels
	ASTM	E standards (E900-2000)	PV Cells & Module integrity
	IEEE	1262	PV Module qualification for performance & reliability
	IEEE	1374	Guide for terrestrial PV power system safety
	IEC	TC82	Solar PV Energy Systems
	FM	4476	Approval Standard for Flexible Photovoltaic Modules
	FM	4478	Approval Standard for Rigid Photovoltaic Modules
	FM	4470	Approval Standard for Singly Ply (<i>Applied to foot traffic for BIPV</i>)
	IEC	61215	Crystalline silicon terrestrial PV modules
	IEC	61646	Thin Film terrestrial PV Modules
	IEC	61853	Performance testing and energy rating of terrestrial photovoltaic modules
	ICC-ES	AC365	Acceptance criteria for BIPV roof covering systems.
	UL	746C/SU 5703	Polymeric Materials - Use in Electrical Equipment Evaluations (PV Junction Boxes)

Electrical	NEC	690	Solar PV systems
	ASTM	E44.09	PV Electrical Power Conversion
	UL	467	Grounding & Bonding Equipment
	UL	2703	Rack Mounting Systems & Clamping Devices for PV (Grounding)
	NEC	Section III, IV, V & VI	Disconnecting Means, Wiring, Grounding & Marking
	UL	4703	PV Wire
	UL	854	Service Entrance Cables (PV USE-2 Wire)
	UL	3730	PV Junction Boxes
	NJ Bill	A 4288	Labeling & External shut off systems for PV
Inverter	UL	1741	Inverters, Converters, Controllers and Interconnection System Equipment
	IEEE	519	Recommended Practice & Req. for harmonic control in electrical power systems
	IEEE	929-2000	Connection of solar systems to the electricity grid
Fire Rating	UL	1703	Fire rating tests for PV
	IBC	2012 1509.7.2	Fire Classification of PV
	IEC	61730-2:2004	PV Module Safety
	ASTM	E44.44	PV System Fire Safety
	UL/ASTM	790-/E108	Standard test methods for fire tests of roof coverings
Installation	NECA	412 (201x)	Standard for installing & Maintaining PV systems
	IFC	105.7.14	PV systems code permit requirements
Module Mounting/Framing	ICC-ES	AC428	Acceptance Criteria for Modular Framing systems used to support PV Modules
	ICC-ES	AC286	Acceptance Criteria for roof flashing for pipe penetrations
	SMACNA	-	Sheet Metal Manual (For PV standoff/pipe penetration)
Design/Installation/Commissioning Best Practices	NRCA	-	Guidelines for Roof systems with Rooftop PV Components
	IFC	2012 605.11	Solar PV power systems
	NRCA	-	Membrane Roof Systems
	NRCA	-	Metal Panel & SPF Roof systems
	CEIR	Centre PV Taskforce	PV Racking Criteria for Effective Rooftop Solar Integration
	NECA	412	Standard for installing PV Power systems
Roof	ASCE	7-02	Minimum Design loads for buildings (Snow & Wind)
	IBC	2012 1509.7.1	Wind Resistance - Rooftop PV
	ANSI/SPRI	RP-4	Wind Design Standard for Ballasted Ply (Applicable to Ballasted PV)
	UL	1897	Uplift Tests for Roof Covering Systems (Applicable to BIPV)

XV. Pre-Job Conference

The NRCA suggests a pre-job meeting be held with the building owner, designer, PV system manufacturer, roof system manufacturer, general contractor, electrical contractor, roofing contractor, and any others whose work may have an effect on successful project completion. The

PV system designer's specifications/plans and flashing details should be reviewed during the pre-job meeting. The following items should also be discussed at the pre-job conference:

- 1) Establish construction schedules and work methods that will prevent damage to the PV system flashing and the roof system.
- 2) Establish procedures for reporting damage to flashings or any part of the roof system.
- 3) Designate access, staging, work, storage, and disposal areas.
- 4) Establish suitable weather conditions and working temperature criteria to which all parties agree.
- 5) Establish safety regulations/requirements and good roofing practices.